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Contents

About the journal..... II

Aims & Scope II

IJBES Editorial Board III

Editorial Statement..... V

Practical Approach for Paving the Way to Motivate BIM Non-users to Adopt BIM.....1-22

A Comparative Review of Building Information Modeling Frameworks… 23-49

Closure Statement…….50

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International Journal of BIM and Engineering Science

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About the journal

International Journal of BIM and Engineering Science (IJBES) is an international, peer reviewed journal, publishing high-quality, original research.

Aims & Scope

IJBES aims to provide researchers and experts with up-to-date research in BIM and its relation with Engineering Science, and to facilitate the global exchange and review of research, ideas and expertise among individuals in the scientific community.

IJBES publishes original peer-reviewed research papers, case studies, technical notes, book reviews, features, discussions and other contemporary articles that advance research and practice in **Building Information Modeling** in architectural, engineering, and construction management, advance integrated design and construction practices, project lifecycle management, and sustainable construction. The journal's scope covers all aspects of **architectural design, design management, construction/project management, engineering management of major infrastructure projects, and the operation and management of constructed facilities**. IJBES also addresses the **technological, process, economic/business, environmental/sustainability, political, and social/human developments that influence the construction project delivery process**.

IJBES strives to establish strong theoretical and empirical debates in the above areas of engineering, architecture, and construction research. Papers should be heavily integrated with the existing and current body of knowledge within the field and develop explicit and novel contributions. Acknowledging the global character of the field, we welcome papers on regional studies but encourage authors to position the work within the broader international context by reviewing and comparing findings from their regional study with studies conducted in other regions or countries whenever possible

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Editorial Statement

It's a pleasure to present the **second** issue in the **second** volume for International Journal of BIM and Engineering Science (IJBES) in **Dec. 2019**. IJBES is one of the scientific journals that BIMarabia s.r.o publish. BIMarabia is a publisher of peer-reviewed, open access academic journals and books. BIMarabia aims to provide researchers, professors and students with up-to-date research in BIM and its relation with Engineering Science, and to facilitate the global exchange and review of research, ideas and expertise among individuals in the scientific community. Established in 2015, BIMarabia has attracted over 20000 scientists worldwide. All content published by BIMarabia offers unrestricted access, and distribution, in any medium; provided the original work is correctly cited. We ensure the highest standards of peer-review for all manuscripts submitted for publication, thanks to the highly qualified scientists who are members of our journal's Editorial Board. BIMarabia delivers support throughout the complete publishing process in an efficient and effective manner.

Architectural, Engineering and Construction (AEC) industry has a giant influence in different nations' economic growth, however, it suffers from myriad problems. AEC industry projects faced issues such as being behind schedule, over budget, inferior quality, low productivity, without sustainability and more. The key players wandered about technology, methodology, or tools that can mitigate or solve these problems. Several researchers and professionals prove that Building Information Modelling (BIM) could help in solving the AEC industry problems. Despite there is no consensus about the definition of BIM; researchers and professionals recognize and appreciate the benefits of using BIM.

Therefore, IJBES concerns about BIM and the related and relevant engineering Science. The **second** volume, **Second** issue, contains two articles. The first one deals with **Practical approach for paving the way to motivate BIM non-users to adopt BIM**. Whereas the second one discusses **A Comparative Review of Building Information Modeling Frameworks**.

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International Journal of BIM and Engineering Science

Dec - 2019; Volume: 2 Issue: 2 page: 01-22 ISSN 2571-1075

Practical approach for paving the way to motivate BIM non-users to adopt BIM

Ashraf Elhendawi[1]*, Hany Omar[2], Emad Elbeltagi[3] , Andrew Smith[4]

Abstract

Typically, the Architecture, Engineering, and Construction (AEC) industry is considered one of the most effective contributor to the national developments worldwide. However, the AEC industry is facing myriad challenges due to the pressing calls for creativity and innovative solutions. Several issues are confronted such as failure to meet client satisfaction, delays in delivering projects on time, cost overruns, low quality, conflicts among parties, safety issues, increasing requests for change orders, tremendous increases in materials waste and project complexity. Building Information Modeling (BIM) is rapidly growing worldwide as a viable tool for improving the efficiency of the AEC industry to solve its salient issues. However, BIM is seldom adopted on the government level, especially in the developing countries. This study aims to explore the stakeholders' perceptions on the benefits of BIM and the barriers that hindered its adoption. Furthermore, practical solutions to motivate BIM non-users to adopt BIM are proposed. A questionnaire was sent to BIM users and non-users in the Kingdom of Saudi Arabia (KSA) as a case study. The key findings that deterred the implementation of BIM were personal correlated issues such as resistance to change and lack of appropriate awareness of BIM. This study convinces the industry players concerning BIM benefits and reveals the barriers and their potential solutions to encourage them to reap the benefits from BIM adoption.

Keywords: BIM barriers, benefits, BIM implementation, AEC, KSA, top management.

1 Introduction:

The AEC industry is considered as the backbone of the economy for several countries worldwide (Elhendawi, et al., 2019). Consequently, the construction industry has substantial impacts on the growth of nations (Giang & Pheng, 2011). For decades, the AEC industry has been suffering from a plethora of problems and lags behind other industries. Client requirements tend not to be achieved, with projects delivered beyond schedule, over budget and with low quality (Ahmed, et al., 2018). AEC is suffering from low productivity, poor efficiency, ineffective performance, low support to sustainability (Azhar, et al., 2015), insufficient environment protection, poor working conditions and loss of control on safety (Latiffi, et al., 2013).

Recently, the construction industry has become more complex to manage (Omar & Dulaimi, 2015). This is due to technical complexity, various data to be managed, continuous changes in the supply chain management systems, contractual provision (Ahmed, et al., 2018), and the pressing demands for smart and green buildings (Marzouk, et al., 2014). As such, several researchers have considered BIM as a

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Available online at: http://bimarabia.com/IJBES/
International Journal of BIM and Engineering Science
Dec - 2019; Volume: 2 Issue: 2 page: 01-22 ISSN 2571-1075

panacea to enhance communication and collaboration among the AEC industry key players (Gerges, M, et al. ،2017 ؛Matarneh & Hamed ،2017).

The roots of BIM can be traced back to the 1970s. However, the AEC industry commenced use of BIM in the 2000s. Since then, several companies and governments have recognised the benefits of BIM and accordingly have adopted BIM (Eastman, et al., 2011).

This study aims to address the main advantages and barriers for BIM users and non-users and to suggest practical solutions that pave the way to overcome the barriers and enhance the chances to reap the utmost benefits of BIM. To that end, an extensive literature review was conducted to grasp the state-of-the-art pertaining to benefits and obstacles experienced by BIM users and non-users.

2 Literature Review:

Currently, BIM has shown its competency to improve AEC industry performance and enhance collaboration among various project parties. BIM is considered a revolutionary technology and process management proposed as a potential solution to the current salient issues in the AEC industry (Azhar, et al., 2015; Love, et al., 2014). BIM was suggested as a tool to support the pre-design phase (Ham, et al., 2008), visualisation interference and clash detection, construction sequencing, cost estimation, fabrication/shop drawings, automated fabrication, code reviews, and data analysis (Forbes & Ahmed, 2011). It also supports construction planning, constructability and analysis, cost and quantity take-off (Autodesk Design Academy, 2017), enterprise resource planning (Elbeltagi & Dawood, 2011), Virtual Reality (VR) (Omar, 2015), Facility Management (FM) (Elhendawi, et al., 2019), project management (Ahmed, et al., 2018) and Augmented Reality (AR) for interactive visualisation (Wang, et al., 2014). Furthermore, construction management education can benefit (Abbas, et al., 2016) as well as health and safety (Ganah & John, 2015), Integrated Project Delivery (IPD) (Glick & Guggemos, 2009), Geography Information System (GIS) (Baik, et al., 2015), Green Building (Marzouk, et al., 2014; Amor, et al., 214) and Lean construction (Zewein, 2017).

As per its perceived benefits, many developed countries such as Canada, UK, Finland, Singapore, Norway, Denmark, South Korea, Australia, Hong Kong and the Netherlands have mandated BIM in their public AEC industry projects, while others have adopted future plans for mandating BIM (Lee, et al., 2014). However, almost all developing countries have not mandated BIM yet (Elhendawi, et al., 2019). From the Gulf Cooperation Council (GCC) members in 2014, only Dubai municipality had mandated BIM in some of its selected large projects.

2.1 The benefits of BIM

The AEC industry, like other industries, benefits from Information and Communication Technology (ICT). Features of BIM could be predestined in different ways depending on how far users have experienced either beginners or experts (McGraw-Hill, 2009). Based on an extensive literature review, Table (1) summarises the most recognised benefits of BIM and the beneficiary party.

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International Journal of BIM and Engineering Science

Dec - 2019; Volume: 2 Issue: 2 page: 01-22 ISSN 2571-1075

Table 1: Perceived benefits of BIM from literature

No.	Benefits of BIM	Stakeholders						Authors
		C*	A/E*	C/SC*	S*	OS*	FM*	
1	Time saving (reduces the time spent on project documentation, communication, and comparing among different options in a very short time)	√	√	√	×	√	×	(Chan, 2014; Doumbouya, et al., 2016; Matarneh & Hamed, 2017)
2	Cost reduction (lowers projects whole cost, design and construction costs, reduced communication cost)	√	√	√	×	√	×	(Doumbouya, et al., 2016; Matarneh & Hamed, 2017)
3	Improved budget and cost estimation	√	√	√	×	√	×	(Elhendawi, et al., 2019)
4	Improving quality (reduced rework, and better design)	√	√	√	√	√	√	(Gerges, M, et al., 2017)
5	Quick and right decisions based on authenticated data	√	√	√	√	√	√	(Harrison & Thurnell, 2014; Love, et al., 2014)
6	Clash detection (check design non-conformities during pre-construction stage, resolve conflicts for different disciplines ahead of construction)	√	√	√	√	√	√	(Matarneh & Hamed, 2017; Gerges, M, et al., 2017)
7	Improve visualization (simulation, representation of the building in an integrated data environment, eliminating the risk of misinterpretation of design)	√	√	√	√	√	√	(Autodesk, 2015; Gerges, M, et al., 2017; Shaban & Elhendawi, 2018)
8	Enhance collaboration and communication between all parties (simultaneous work by multiple disciplines)	√	√	√	√	√	√	(Autodesk, 2015; Matarneh & Hamed, 2017; Ahmed, et al., 2018)
9	Maintain control through the entire project life cycle	√	√	√	√	√	√	(Matarneh & Hamed, 2017)
10	Reduce risks	√	√	√	√	√	√	(Jernigan, 2014)
11	Support construction and project management (executive, communication, strategic planning, site planning, risk management, change plans, improved safety, added value, and better facility management)	√	√	√	√	√	√	(Latiffi, et al., 2013; Chan, 2014; Gerges, et al., 2016; Matarneh & Hamed, 2017)
12	Reduce accidents by promoting safety plans	√	×	√	×	√	×	(Moreno, et al., 2013)
13	Error-free design	√	√	√	√	√	√	(Almutiri, 2016)
14	Reduced requests for information (RFIs') (promote project understanding and eradicates any ambiguity)	√	√	√	√	√	√	(Azhar, et al., 2011; Abbasnejad & Moud, 2013)
15	Early involvement for client	√	√	√	√	√	√	(Jernigan, 2014; Omar, 2015)
16	Promote the client and customer satisfaction	√	√	√	√	√	√	(Karna, et al., 2009)
17	Keep stakeholders informed and satisfied	√	√	√	√	√	√	(Jernigan, 2014)
18	Maximising productivity	√	√	√	√	√	√	(Matarneh & Hamed, 2017)

Available online at: http://bimarabia.com/IJBES/

International Journal of BIM and Engineering Science

Dec - 2019; Volume: 2 Issue: 2 page: 01-22 ISSN 2571-1075

19	Availability of data throughout the project lifecycle	√	√	√	√	√	√	(Gerges, M, et al., 2017)
20	Reduced Document Errors and omissions	√	√	√	√	√	√	(Autodesk, 2015)
21	Minimising changes (significantly reduce change orders)	√	√	√	√	√	×	(Matarneh & Hamed, 2017)
22	Enhance site logistic plans	√	×	√	√	√	√	(Saleh, 2015)
23	Enhance lean construction principle and value engineering	√	√	√	√	√	√	(Zewein, 2017; Khalil, 2017)
24	Promote value for money	√	√	√	√	√	√	(Elmualim & Gilder, 2014)
25	Increase efficiency (faster and more effective processes and methods)	√	√	√	√	√	√	(Doumbouya, et al., 2016; Matarneh & Hamed, 2017)
26	Improve building sustainability analyses	√	√	√	√	√	√	(Eadie, et al., 2013; Doumbouya, et al., 2016)
27	Creative and innovative solutions	√	√	√	√	√	√	(Azhar, 2011; Chan, 2014)
28	Automated assembly	√	×	√	√	√	√	(Azhar, et al., 2015)
29	Reduce waste (the elimination of waste and value generation)	√	√	√	√	√	√	(Omar & Dulaimi, 2015; Autodesk, 2015)
30	Enhance competitiveness (promote the company's competitive advantages)	√	√	√	√	√	√	(National Building Specification, 2014; Azhar, et al., 2015)
31	Facility management (during preconstruction and construction)	√	√	√	√	√	√	(Sabol, 2008; Omar, 2015)
32	Facility maintenance (easy access to data for efficient O&M)	√	√	√	√	√	√	(Elhendawi, et al., 2019)
33	Reduced claims and legal cases (reduced litigation and dispute claims)	√	√	√	√	√	√	(Liu, et al., 2010; Construction, M.H, 2012)
34	Improved accuracy	√	√	√	√	√	√	(Liu, et al., 2010)
35	Promote profits	√	√	√	√	√	√	(Construction, M.H, 2012)
36	Punctual procurement (reduce the inventory duration and order materials Just In Time)	√	√	√	√	√	√	(Chan, 2014; Gerges, et al., 2016)
37	Promote prefabrication for better quality	√	x	√	√	√	√	(Elbeltagi & Dawood, 2011; Bryde, et al., 2013)
38	Designers becoming more knowledgeable in the construction processes	√	√	√	√	√	√	(McCartney, 2010)
39	Maintain repeat business	√	√	√	√	√	√	(Construction, M.H, 2012)
40	Market new business (offers new services such as reality capture)	√	√	√	√	√	√	(Construction, M.H, 2012)
41	Better distribution for human resources	√	√	√	√	√	√	(Construction, M.H, 2012; Chan, 2014)
42	Quick and easy integration of new team members	√	√	√	√	√	√	(Jernigan, 2014)
43	Overcoming distance barriers	√	√	√	√	√	√	(Eastman, et al., 2011)

Available online at: http://bimarabia.com/IJBES/

International Journal of BIM and Engineering Science

Dec - 2019; Volume: 2 Issue: 2 page: 01-22 ISSN 2571-1075

44	Promote the designers' capacity and increase the competition	√	√	√	√	√	√	(Eastman, et al., 2011; Samuelson & Björk, 2013)
45	Bridge the capacity gaps with the international AEC professionals	√	√	√	√	√	√	(Eastman, et al., 2011)
46	As-built drawings (laser scanning for existing properties)	√	√	√	x	√	√	(Love, et al., 2014; Volk, et al., 2014)
47	Computer-aided facility management (CAFM) information requirement	√	√	√	√	√	√	(Elhendawi, et al., 2019)
48	Offsite accessibility, access the model and project details from anywhere	√	√	√	√	√	√	(Autodesk, 2015)
49	Augmented reality for interactive architectural visualisation	√	√	√	√	√	√	(Wang, et al., 2014; Omar, 2015)
50	GIS integrated with BIM	√	√	√	×	√	×	(Baik, et al., 2015)
51	Conformity with specifications, standards, and codes	√	√	√	√	√	√	(Eastman, et al., 2011; Sebastian, 2011)

*C (Client), A/E (Architect/Engineer), C/SC (Contractor/Subcontractor), S (Supplier), OS (Other Stakeholders), FM (Facility Management)

Eastman et al. (2008) claimed that the client is the only party reaping the full benefits of BIM. This claim aligns with the findings in Table (1), which explicitly demonstrated that the client is the party benefitting most from the implementation of BIM with the highest score of benefits i.e. 51 out of 51. However, each party acquires the benefits of BIM based on their business function.

Salla (2014) summarised the top fifteen benefits gained from using BIM in the following order; (1) Reduce errors and omissions in the design phase, (2) Improve collaboration with owner/design firms during the construction phase, (3) Enhance organisational image, (4) Reduce rework, (5) Lower construction cost, (6) Improve cost control and predictability, (7) Reduce the overall project duration, (8) Market new business, (9) Offer new services, (10) Increase profits, (11) Maintain business sustainability, (12) Reduce cycle time of workflows, (13) Faster client approval cycles, (14) Improve safety, (15) Faster regulatory approval cycles.

2.2 BIM Barriers

Azhar et al., (2015) reported that, despite the advantages of implementing BIM in construction projects and the rapid growth of BIM adoption, several organisations in developing countries are facing various challenges and obstacles hindering the implementation of BIM, which has made it a laborious task. Barriers of BIM are perceived differently from two points of view, those of BIM users and those of non-users (Eadie, et al., 2014).

Panuwatwanich, et al., (2013) and Omar (2015) highlighted the top barriers for implementing BIM, are "lack of management commitment to implement BIM" and "the remarkable lack of *know-how* to switch to BIM and to manage the challenges and obstacles". Above all, "the resistance to change, and clinging to the old ways of working" was reported as the major reason for the cumbersome adoption of BIM in the AEC industry, specifically in the Middle East and North Africa (MENA).

According to McGraw-Hill (2012) the top seven barriers that hindered BIM implementation are interoperability, functionality misperception, unidentified BIM deliverables among parties, clients refraining to ask for BIM, shortage of BIM competencies and the need for a 3D building product manufacturer.

Available online at: http://bimarabia.com/IJBES/

International Journal of BIM and Engineering Science

Dec - 2019; Volume: 2 Issue: 2 page: 01-22 ISSN 2571-1075

Banawi (2017) asserted that, BIM non-users summarised the salient issues precluded implementation of BIM as there is insufficient demand from clients, there has not been sufficient time to evaluate BIM. Moreover, software and hardware upgrades are too expensive. BIM non-users claimed that BIM functionality does not apply very well to what they do and there is insufficient BIM-compatible content available for industry needs. Table (2) portrays the classifications of the barriers and classifies them into: Personal Barriers, Process Barriers, Business Barriers, Technical Barriers, Organization Barriers and Market Barriers.

Table 2: BIM Recognized Barriers for the AEC industry

No.	The barriers	Authors
Personal Barriers		
1	Insufficient education and training	(Banawi, 2017; Matarneh & Hamed, 2017)
2	Lack of true understanding of what BIM is	(Bryde, et al., 2013; Alhumayn, et al., 2017)
3	Cultural issues resulting in resistance to change	(Almutiri, 2016; Gerges, M, et al., 2017)
4	Lack of BIM knowledge pertaining to current and emerging technologies	(Saleh, 2015)
BIM Process Barriers		
1	The required collaboration, integration, and interoperability	(Banawi, 2017)
2	Not all stakeholders are using BIM	(Linderoth, 2010; Elmualim & Gilder, 2014)
3	Legal and contractual challenges (ownership of data, traditional procurement methodology)	(Chien, et al., 2014; Eadie, et al., 2014; Azhar, et al., 2015).
4	Risks and challenges with the use of a single model (BIM)	(Saleh, 2015; Banawi, 2017)
5	Changing work processes (Lack of effective collaboration among project participants)	(Saleh, 2015)
Business Barriers		
1	Time and cost required to train new users	(Gerges, et al., 2016)
2	Cost implications at the outset of BIM implementation pertaining to purchasing software licenses, hardware upgrade, training cost and time	(Gerges, et al., 2016; Gerges, M, et al., 2017; Matarneh & Hamed, 2017)
3	Unclear benefits	(Construction, M.H, 2012; Saleh, 2015)
4	The complicated and time-consuming modeling process	(Alhumayn, et al., 2017; Gerges, M, et al., 2017)
5	Have not had sufficient time to Evaluate, most construction players adopt “watch and see” strategy	(Construction, M.H, 2012; Omar, 2015)
6	Uncertainty for Return on Investment (ROI)	(Azhar, 2011; Saleh, 2015)
7	Lack of contractual arrangements	(Harrison & Thurnell, 2014; Banawi, 2017)
8	Absence of imperative policy from the government to mandate BIM	(Elhendawi, et al., 2019)
Technical barriers		
1	Lack of BIM specialists	(Bui, et al., 2016; Gerges, M, et al., 2017)
2	Absence of customised standards and clear guidelines	(Volk, et al., 2014; Matarneh & Hamed, 2017)
3	Difficulty of updating the information in BIM (time-consuming)	(Chan, 2014; Volk, et al., 2014)
4	BIM still utilized as a tool i.e. “object-based modeling” or “model-based collaboration”, whereas BIM users should seek to reach to “network-based integration”	(Succar, et al., 2013)
5	Insufficient infrastructure-based technology	(Chan, 2014; Bui, et al., 2016)

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International Journal of BIM and Engineering Science
Dec - 2019; Volume: 2 Issue: 2 page: 01-22 ISSN 2571-1075

6	Inefficient Interoperability	(Chan, 2014)
7	BIM file sizes are too large. Transporting, manipulating, storing or sharing these large files is difficult	(Liu, et al., 2010)
8	Updating of information	(Chan, 2014; Volk, et al., 2014)
9	Current technology is enough	(Saleh, 2015; Gerges, M, et al., 2017)
Organisation Barriers		
1	Lack of government support	(Bui, et al., 2016; Matarneh & Hamed, 2017)
2	Difficulties in managing the change to BIM	(Chien, et al., 2014; Azhar, et al., 2015)
3	Absence of other competing initiatives	(Saleh, 2015; Omar, 2015)
4	Resistance to change/unwillingness to change	(Jernigan, 2014; Omar, 2015)
5	BIM compels drastic changes in the organizational chart and the workflow	(Memon, et al., 2014; Volk, et al., 2014; Gerges, M, et al., 2017)
6	Lack of BIM experience (know-how) to switch from non-BIM to BIM users	(Elhendawi, et al., 2019)
7	Cost correlated to hardware upgrades and software purchase	(Arayici, et al., 2009; Construction, M.H, 2012)
8	Organisational financial stand	(Chien, et al., 2014; Azhar, et al., 2015)
Market Barriers		
1	Low level of adoption due to poor awareness about BIM	(Gerges, et al., 2016; Matarneh & Hamed, 2017)
2	The wrong grasp of BIM, as it tends to be introduced by software developers, accordingly the market is overdue at the embarking stage for switching to BIM	(Porwal & Hewage, 2013; Banawi, 2017)
3	Lack of client/government demand	(Gerges, et al., 2016; Gerges, M, et al., 2017)
4	Clients not lending appropriate support to the benefits of BIM	(Banawi, 2017)

Based on the extensive literature survey, there is a duet of BIM benefits and there is a lack of consensus on the barriers. In order to bridge this gap in knowledge, this research investigated these benefits and barriers and paves the way for swift and smooth implementation of BIM.

3 Research Methodology and Data Collection:

The literature review developed a profound understanding of the perceived benefits and barriers that hindered the implementation of BIM. The research adopted the overarching method, which involved a quantitative approach via a structured questionnaire, followed by a qualitative approach via face-to-face interviews with carefully selected veterans from the KSA construction industry.

The Kingdom of Saudi Arabia (KSA) provides a good example to represent the developing countries in the Middle East that suffer from the barriers and obstacles overburdening the implementation of BIM. Moreover, KSA embraces several international organizations originating in developed countries, which bring good experience in the BIM realm.

The literature study assisted the development of a structured questionnaire survey. This survey was distributed via email to randomly selected professionals who work in the KSA, especially, those who are registered in Saudi Commerce Chambers which includes the entire KSA AEC industry players. In addition to organisations that are registered in the Ministry of Municipal and Rural Affairs, additionally, Saudi Council of Engineers published the questionnaire in its monthly magazine.

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International Journal of BIM and Engineering Science
Dec - 2019; Volume: 2 Issue: 2 page: 01-22 ISSN 2571-1075

Pilot sample: Prior to finalising the questionnaire, the survey was distributed to a pilot sample of a randomly selected 12 professionals with average experience of 8 years in the KSA AEC industry. Half of them represented BIM users and the other half represented non-users. These veteran professionals were selected from local and multinational AEC organisations in the KSA market. The initial questionnaire was refined based on the feedback received from the pilot sample.

Afterwards, the final questionnaire was accessible via the online survey platform "Google forms". This platform enabled easy and swift completion of the survey via the internet and then the responses were gathered automatically to save and store them via an online database.

Traditionally, the response rate for online surveys is suboptimal by 11% compared with other techniques (Saunders, et al., 2012). The link to an online questionnaire was sent by email to increase confidentiality and anonymity. The questionnaire was available from 20th September 2019 to 20th December 2019.

The questionnaire survey consisted of ten sections. Section one consisted of general information, respondents' personal information and demographics such as profession, years of experience in KSA, academic qualifications. Section two consisted of respondents' awareness of BIM, BIM user or non-user, BIM Software that their company use, BIM applications, beneficial integrating with BIM, BIM maturity levels, the future of BIM …. etc. In section 5, 6, 7, 8, 9 and 10 each respondent was asked to rate to what extent he/she agrees/disagrees with each of the perceived benefits of BIM, and barriers for BIM implementation on a five-point Likert scale ranging from 1 to 5, where 5 represents 'Strongly agree', and 1 represents "Strongly disagree".

The questionnaire was developed to collect the data from BIM users and BIM non-users who worked in the KSA AEC industry. The questionnaire survey was sent to 689 AEC medium to large organisations in the KSA. There were 275 responses (40%), but of those, incomplete responses were 27 (9.7%) of the returned responses. Therefore, the number of true responses was 248 (90%) of the returned responses.

4 Results analysis:

4.1 Respondents' general information

The received responses are 248 while 63% of the respondents do not have enough knowledge about BIM. However, 37% have good BIM knowledge. This percentage unveiled that there is a lack of awareness about BIM in the KSA. In fact, this recent survey opposes the conclusion made by Farah (2014) who reported that there is a high level of awareness of BIM in the KSA AEC industry. Figure (1) demonstrates the reasons for which some respondents are reluctant to adopt BIM.

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International Journal of BIM and Engineering Science

Dec - 2019; Volume: 2 Issue: 2 page: 01-22

ISSN 2571-1075

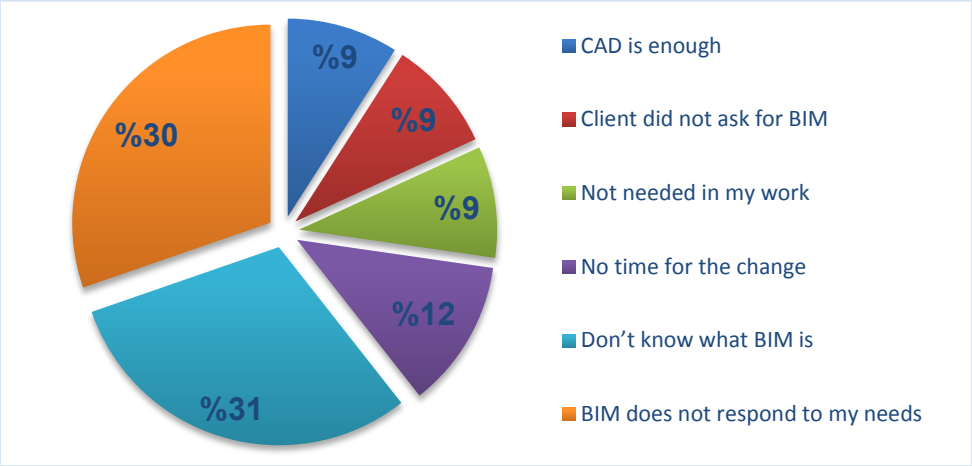

Figure 1: Reasons for which BIM non-users are not interested in BIM adoption

It is obvious, "the lack of awareness of what BIM is" is the main hindrance precluding the adoption of BIM in the KSA. Consequently, BIM non-users do not know how to leverage the benefits from BIM. This warrants crucial action from the government and its subsidiaries to raise the awareness for BIM non-users, and to recognise the utilities of BIM. It is worthy to mention that, the true completed responses represented 25.5% public organisations and 74.5% private organisations. This portrays that the public sector is less interested in BIM compared with the private sector who embraces various international organisations.

Figure 2 illustrates that, about 50% of respondents have less than 10 years of BIM experience, which reflects the low level of BIM awareness. Raising the awareness among the AEC industry plays pivotal role for overcoming the barriers and obstacles that hinder BIM implementation. Furthermore, raising awareness of BIM for undergraduate and post graduate students is seen as the cornerstone to develop a new generation with BIM knowledge.

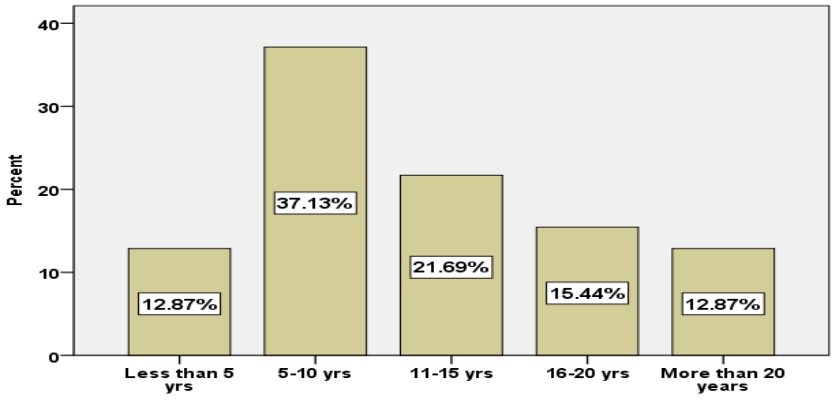

Figure 2: Respondents years of experience

4.2 Respondents perceptions about BIM

The respondents' answers for different areas of BIM application are reported in Table (3). This result conforms with several claims in the literature studies.

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International Journal of BIM and Engineering Science

Dec - 2019; Volume: 2 Issue: 2 page: 01-22 ISSN 2571-1075

Table 3: BIM Applications

BIM Applications	Responses	
	N	Percent
Safety	23	4.1%
Interaction with non-professionals	38	6.8%
Site layout planning	42	7.6%
Support constructability and analysis	42	7.6%
Collaboration	47	8.5%
Project scheduling and programming	52	9.4%
Material take-off for tendering	53	9.5%
Cost Estimating	60	10.8%
Design analysis	62	11.2%
Quantity Surveying	66	11.9%
Production of shop-drawings/as-built drawings	71	12.8%

Table (4), presents the various areas that can be integrated with BIM as per the respondents' answers. Project management came as the first area that is usually integrated with BIM. These results coincide with the literature studies.

Table 4: Integration with BIM

Integration with BIM	Responses	
	N	Percent
Health and Safety	37	6.4%
Augmented reality	38	6.6%
Enterprise Resource Planning (ERP)	39	6.8%
Computer-aided facility management (CAFM)	39	6.8%
Geography information system (GIS)	41	7.1%
Facility Maintenance	45	7.8%
Integrated Project Delivery (IPD)	48	8.4%
Construction Management Education	49	8.5%
Lean Construction	50	8.7%
Green Building	54	9.4%
Virtual Reality	57	9.9%
Project Management	77	13.4%

Figure 3 measured the maturity levels of BIM amongst the BIM user participants, showing that BIM adoption is still within level 1, with a percentage of 35.51%. These results support the authors' claim that "the developing countries are still struggling in the embarkation stage of BIM implementation".

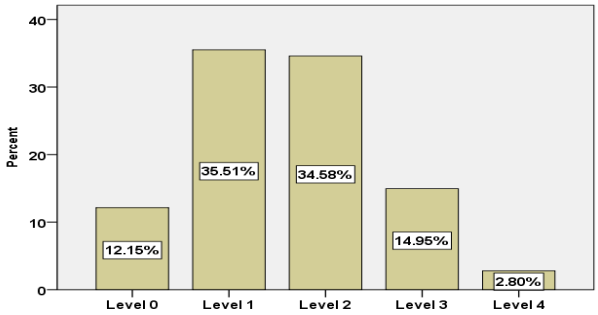

Figure 3: BIM maturity levels

As BIM is still in its embarking stage it is realistic to find that most BIM users are utilizing BIM as a 3D model. Figure (4) shows that more than 67% of BIM users utilize BIM only for 3D modelling.

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International Journal of BIM and Engineering Science

Dec - 2019; Volume: 2 Issue: 2 page: 01-22

ISSN 2571-1075

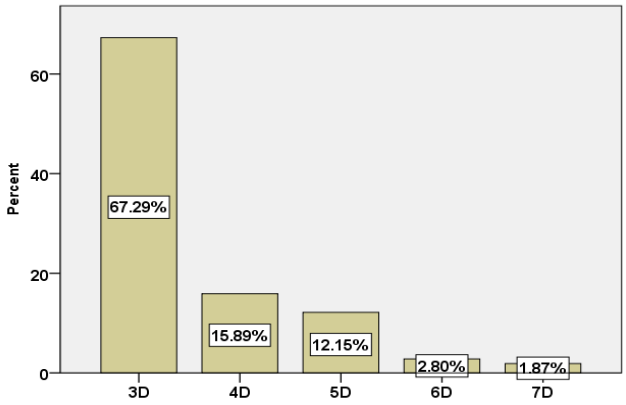

Figure 4: The current implementing Dimension of BIM in respondents' projects

As BIM is rapidly growing worldwide, Figure 5 shows that more than 70% of respondents expect that BIM will sooner or later be mandated in the AEC industry worldwide.

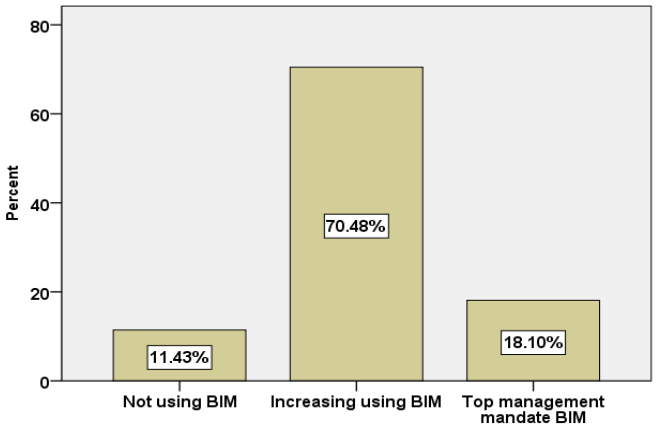

Figure 5: The future of BIM

4.3 Perceived benefits of BIM

There is a close understanding of the perceived benefits of BIM between the BIM users and non-users, chiefly the advantage of meeting client satisfaction. BIM users believe in the capability of BIM to consolidate the team works and provide a competitive advantage to the firm much higher than BIM non-users, it is realistic, because only BIM users can acquire these advantages.

Generally, the expectations of BIM non-users are much more than BIM users pursuant to the advantages of BIM. The biggest difference for the perceptions of the two groups is found in the ability of BIM to "save the time" which was considered the first by BIM non-users and at the end by BIM users. Similarly, for the benefit "BIM offers improved productivity". These big discrepancies can be understood from the ideal state that BIM non-users are considering, which can be achieved only after the AEC market reaches the full maturity level of BIM.

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International Journal of BIM and Engineering Science
Dec - 2019; Volume: 2 Issue: 2 page: 01-22
ISSN 2571-1075

4.3.1 Client perspective

Figure 6: Benefits of BIM from the Client's perspective

Figure 6 portrays the client responses. Respondents claim that benefits of BIM from clients' perspectives are as follows: BIM is distinctive to clients for time-saving, completing projects on time, minimising coordination problems, improving quality, assuring like for like comparison during the tender stage, earlier involvement of client in the design stage and reducing cost. Furthermore, some respondents emphasised the crucial need to start BIM at the outset of the project, not at a later stage as it disturbs the processes which may cause delays instead of progress.

4.3.2 Designer perspective

Table 5 shows the designers' responses for their perceived benefits of BIM. They have considered BIM is distinctive for enhancing their experience through allowing various options in a short duration, quick review, and the time required to make changes on the model is very short compared with CAD conventional approaches. Moreover, BIM improves coordination, avoids clashes and tremendously reduces design errors. It also boosts information sharing and enables quick quantity take-off. Ahmed, et al. (2018) mentioned, the aforementioned benefits of BIM as generic benefits for all project parties.

Table 5: Benefits of BIM from the Designers' perspective

Benefits	Weighted mean	Std. Deviation	Ranking	The general trend
Producing Various design options	3.97	1.045	3	Agree
Facilitating visual evacuation plans	4.06	.864	1	Agree
Enabling Sustainable analysis	3.98	.980	2	Agree
Extracting fast IFC drawings	3.97	1.045	3	Agree
Weighted mean	**3.995**			**Agree**

4.3.3 Contractor perspective

Figure 7 illustrates the contractors' responses for their perceived benefits of BIM. They have considered BIM is distinctive for improving coordination and collaboration among different project stakeholders, it enables cost savings, allows visualisations that give a clear and full picture for effective planning, BIM tools assist the project team to reduce the cost and control the budget. Clash detection tool enables detection of clashes in the design prior to starting construction, which reduces conflicts and disputes. 4D BIM tool enables accurate inventory, improves facility management and increases productivity.

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Dec - 2019; Volume: 2 Issue: 2 page: 01-22 ISSN 2571-1075

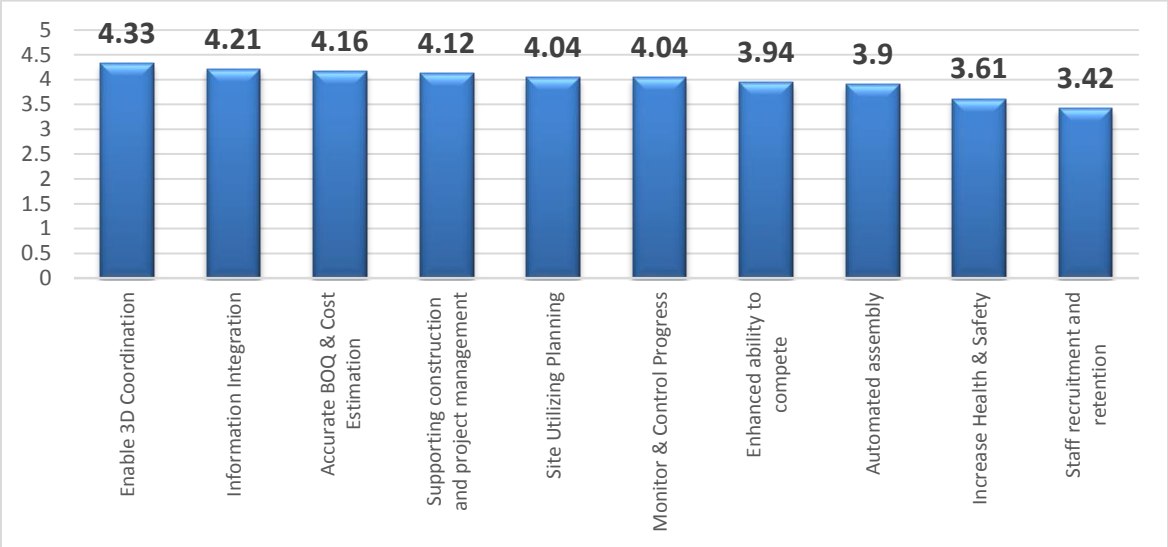

Figure 7: Benefits of BIM from the contractors' perspective

One respondent concluded that BIM provides excellent coordination, good presentation and predicts issues before their occurrence. Furthermore, another respondent pointed out that BIM enhances bid accuracy with model-based estimation and improved coordination with schedule visualisation. These results align with the conclusions of (Bui, et al., 2016).

4.3.4 Common benefits (to all participants)

According to the data analysis, the common benefits of BIM that all disciplines have experienced are ranked hereinafter in Table 6.

Table 6: Benefits of BIM to all participants (i.e. client, designer, and contractor)

Benefits	Weighted mean	Std. Deviation	order	The general trend
Time savings	4.20	1.035	2	Agree
Cost saving	4.12	1.082	5	Agree
Quality improvement and Reduced Rework	4.19	1.062	3	Agree
Clash detection	4.29	1.094	1	Strongly agree
Improves visualisation	4.06	1.096	7	Agree
Reduced number of requests for information	4.06	1.096	7	Agree
Reduced change orders	4.06	1.096	7	Agree
Enhanced collaboration and communication	4.16	1.035	4	Agree
Reduced document errors	4.10	1.052	6	Agree
Reduced disputes, claims and lawful issues	3.90	1.052	9	Agree
Reduced waste and promotes value engineering	3.98	1.097	8	Agree
Increasing efficiency	4.19	1.050	3	Agree
Creation and sharing of information ability: Life cycle data	4.12	1.100	5	Agree
Weighted mean	**4.11**			**Agree**

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International Journal of BIM and Engineering Science
Dec - 2019; Volume: 2 Issue: 2 page: 01-22 ISSN 2571-1075

Figure (8) shows the benefits to all project parties. Clearly the client is the most benefited party from BIM followed by designers and contractors. This result is close to Eastman, et al., (2008) conclusions, wherein, they ordered the BIM beneficiaries as the client, then design bodies and the contractor.

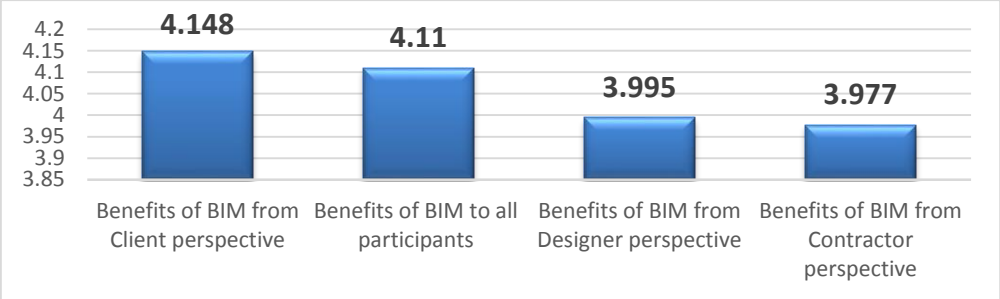

Figure 8: Perceived benefits of BIM

4.4 Salient Barriers Detering BIM Implementation

Data analysis explicitly manifesting that, challenges are keyed to change management alongside lack of competencies are the main barriers hindering the wide adoption of BIM. Additionally, the absence of government imperative policy for mandating BIM resulted in poor adoption of BIM as it became an optional choice, for which most of SMEs averted utilisingutilizing BIM.

4.4.1 Personal Barriers

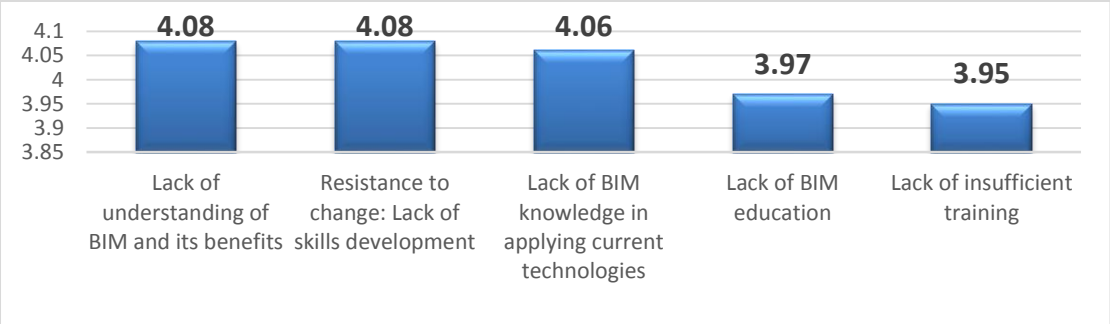

Figure 9: Personal Barriers

Figure 9 illustrates the personal correlated barriers that diminish implementation of BIM. Respondents reported that the personal barriers could be cultural issues, in that many people involved in a construction area are afraid to share their data for lack of mutual trust and other reasons, lack of advertisement in magazine and news on TV, insufficient fund, shared risk-reward, and lack of conduct long-term relationships.

Pursuant to the data analysis, "resistance to change" and the implicit feeling of being safe in the comfort zone, deters any advocate for change. Moreover, “lack of understanding of the benefits of BIM, and what BIM is” converted several decision makers to be hostile against the change towards BIM. They even considered BIM is useless and has no value to their business. Lack of sufficient BIM knowledge, training and education are of importance to change the current stagnant status.

A quote from one respondent portrayed lack of BIM knowledge, stating that “I am sure BIM designers do not have the enough experience to develop a cost effective and safe design. Furthermore, Not everything on a computer screen can be built in real life.”

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International Journal of BIM and Engineering Science
Dec - 2019; Volume: 2 Issue: 2 page: 01-22
ISSN 2571-1075

4.4.2 Process Barriers

Table 7 illustrates the respondents' perception of process barriers. They have considered "changing the work processes" alongside "lack of effective collaboration among project participants" are the most influential attributes that hindered BIM implementation. Moreover, the risks and challenges of using a single model was ranked the second factor that hindered the utiliasation of BIM. However, legal issues pertaining to the model ownership ranked the last as several contract documents still overlook this issue and disputes loom after the project completion between the design bodies and the client.

Table 7: BIM Process Barriers

Barriers	Weighted mean	Std. Deviation	Ranking	The general trend
Legal issues (ownership of the model)	3.51	1.033	3	Agree
Risks and challenges with the use of a single model (BIM)	3.57	1.031	2	Agree
Changing work processes	3.78	1.032	1	Agree
Lack of effective collaboration among project participants	3.78	1.032	1	Agree
Weighted mean	**3.66**			**Agree**

4.4.3 Business Barriers

Figure 10 demonstrates the business barriers that impacted BIM implementation. Data analysis revealed that, the time and cost to train the staff ranked as the most significant factor deter the implementation of BIM, followed by, the lack of contractual agreements that clarifies the responsibility of each party. Moreover, the long time required for developing BIM model and uncertainties for return on investment (ROI) due to high costs of implementation are raised as third, fourth and fifth factors respectively. These results are in agreement with Shaban and Elhendawi (2018) findings.

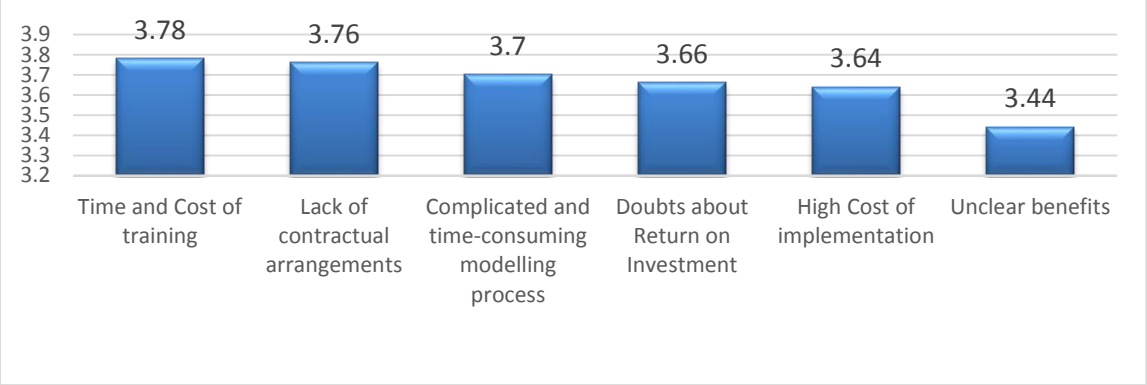

Figure 10: Business Barriers

4.4.4 Technical Barriers

Table 8 summarises the respondents' perspectives about technical barriers. Respondents considered "lack of BIM technical experts" has the most devastative impacts on the implementation of BIM. Additionally, "Absence of national BIM standards and clear guidelines" converted the adoption of BIM as a cumbersome task. Changing or upgrading the technology infrastructure such as upgrading the hardware and purchasing software licenses, and the correlated costs and business disturbance, demotivate decision makers to change towards BIM.

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International Journal of BIM and Engineering Science
Dec - 2019; Volume: 2 Issue: 2 page: 01-22
ISSN 2571-1075

Table 8: Technical Barriers

barriers	Weighted mean	Std. Deviation	Ranking	The general trend
Lack of BIM technical experts	3.85	1.105	1	Agree
Interoperability	3.66	1.027	4	Agree
Absence of standards and clear guidelines	3.78	1.076	2	Agree
Insufficient technology infrastructure	3.69	1.103	3	Agree
Current technology is enough	3.33	1.240	5	Neutral
Weighted mean	**3.662**			**Agree**

4.4.5 Organization Barriers

The organisational barriers are as illustrated in Figure 11. Lack of management support and fear of changes are ranked the first and second most influential factors impeding the implementation of BIM in KSA. Noticeably, these findings are similar to the findings concluded by Shaban and Elhendawi (2018) in Syria. Furthermore, respondents detailed that the organisation barriers stemmed from company policy, futile coordination, top management experience, fear of change, unavailability of competencies, and absence of leadership.

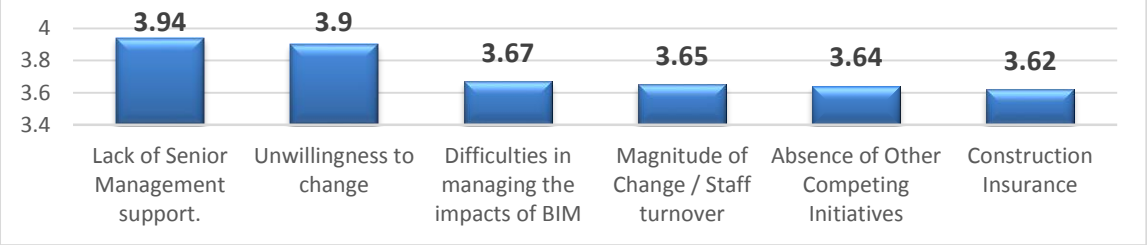

Figure 11: Organisation Barriers

4.4.6 Market Barriers

Market barriers are shown in Figure 12. Clearly, the lack of client and/or government demand for BIM was ranked the first as the most important factor that hindered the implementation of BIM. In the same context Omar (2015) claimed that the market is not ready yet. There is a great deal of consensus among the respondents, as there is a significant role incumbent upon the government, to mandate BIM. As such, the market will be ready to adopt BIM.

According to data analysis, the market barriers are seen in the low realization of the benefits of BIM, understanding the importance of BIM, and the lack of competencies as well as stewardship.

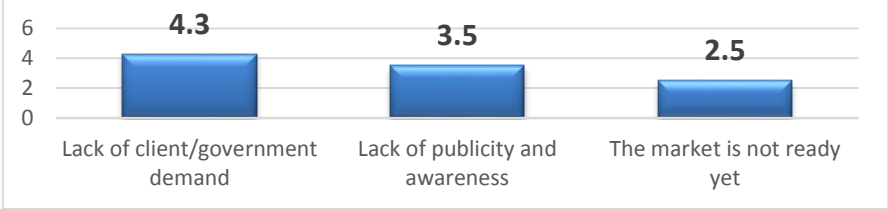

Figure 12: Market Barriers

In order to recognise the hierarchy of the causes that resist the implementation of BIM, Figure (13) illustrates all the six categories under which the challenges were included. It is not a surprise to know that, personal barriers are ranked the first with a significant difference compared to all the other categories. Therefore, plans to propose incentives and catalysts should be put forward to motivate the

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International Journal of BIM and Engineering Science
Dec - 2019; Volume: 2 Issue: 2 page: 01-22 ISSN 2571-1075

people to adopt BIM. Indeed, BIM has its three pillars which starts with People and then Process and Technology (Eastman et al., 2011).

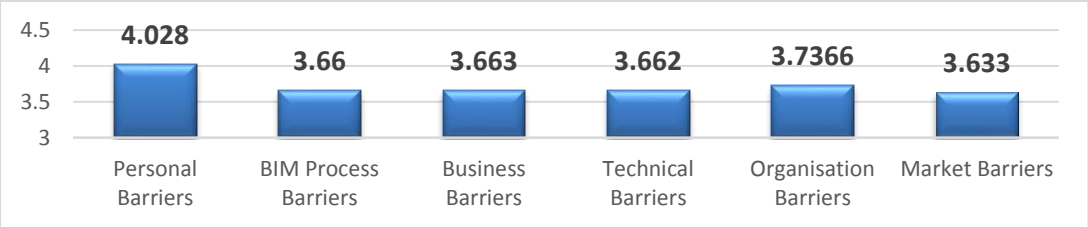

Figure 13: The barriers to implementing BIM

4.5 Paving the way to facilitate the adoption of BIM

The respondents recommended several ways to overcome the barriers as follows:

The resistance to change represents the most barriers to hinder BIM implementation and need more effort to remove it. To solve this issue, local companies could seek partnerships with international construction companies that have accomplished projects using BIM-based technologies and processes.

The top management has an indispensable role in leading the organisational change to BIM, so they should be fully aware of the organisational benefits of BIM to improve the performance for adding competitive advantage and increasing the profits. Therefore, top management should be convinced to support this change to take the decision of utilizing BIM.

Furthermore, to expedite BIM implementation the mixed approaches should be adopted concurrently, Bottom-up and top-down. The effective change commences from the employees' which must be supported by top management.

For the sake of providing the market with BIM skilled resources for long term basis, governments should guide and support the universities for the enclosure of BIM within the curriculums for undergraduate and postgraduate students. Moreover, universities together with BIM software vendors should collaborate to raise awareness of BIM throughout series of free training sessions.

Industry Foundation Classes (IFC) enable the opening or importing of BIM files to reuse the created data in other applications using different software; IFC schemes can overcome the conflicts that may appear of using different software of BIM models.

Assigning a model manager or so called BIM manager is essential to manage the BIM model-related issues.

Model correlated issues such as ownership can be easily settled by endorsing a clear clause in the contract documents to clarify this issue. However, New Zealand handbook (2014) have clarified this issue as follows, the designers will acquire a prior consent from the owner to use the model and vice versa, the owner will request the designer's approval to reuse the model.

Integrated project delivery (IPD) was proposed to be the appropriate construction procurement strategy suitable for BIM, where IPD is defined as a "project delivery approach that integrates people, system, business structures, and practices into a process that collaboratively harnesses the talents and insights

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International Journal of BIM and Engineering Science
Dec - 2019; Volume: 2 Issue: 2 page: 01-22 ISSN 2571-1075

of all participants to optimize project results, increase value of owner, reduce waste, and maximize efficiency through phases of design, fabrication, and construction"

5 Conclusions:

The focus of the construction industry now is to eliminate waste and inefficiency to improve quality and profitability. This research extensively investigated the benefits and the barriers that hinder the implementation of BIM within the KSA AEC industry as the cornerstone for proposing solutions to pave the way for KSA construction industry to implement BIM.

The key findings pertaining to the benefits of BIM are: (1) the richness of the information within the BIM Model enhanced the collaboration among stakeholders, (2) Reduced financial risk, (3) Improved project performance, (4) accurate BOQ and cost estimation, (5) promoted the off-site prefabrication, (6) increasing profitability and (7) reduced change orders and disputes.

Moreover, the top barriers deterring BIM implementation are: (1) There is low level of BIM awareness about BIM in the AEC industry, (2) lack of top management support, (3) lack of government demand for BIM, (4) resistance to change, (5) Lack of BIM technical experts and (6) time and cost required for switching to BIM. For appropriate implementation of BIM, lessons learned from earlier BIM users such as UK, USA, Australia, and New Zealand must be taken into consideration to learn from their pitfalls.

This research suggested developing strategic plans relying on collaboration among government, private and public sectors to overcome all barriers. For instance, to overcome insufficient education and training software providers should collaborate with government entities, and universities to educate and train employees and university students (as a long-term solution) to respond to the needs of BIM experts.

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A Comparative Review of Building Information Modeling Frameworks

(A Review article of Building Information Modelling Frameworks)

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Abstract:

The building sector influences the Gross Domestic Product (GDP) of many countries. There is a vast amount of waste generated in the building process, with many projects suffering from delivery delays, running over budget, and resulting in buildings of minimal quality. Building Information Modeling (BIM) has shown great potential towards solving these problems. BIM sets frameworks for Architects, Engineers, and Contractors (AEC), enhancing management of the building process. This paper analyzes select framework methods, tools, and processes, identifying key guidelines required to create a BIM framework customized to local requirements; this will have a positive effect on the construction industry by lowering the cost of buildings and improving the communication among parties, and leading to the development of frameworks based on local indicators. A comprehensive literature review was conducted to determine components and factors from structure frameworks with the main findings then classified and categorized into the following sectors -- government support, maturity level measurement, standards, protocol, database, and education plan. This permits the development of a comparison highlighting the frameworks' differences and summing up possible strategies for BIM implementation on several bases, such as region differentiation and the local industries' Political, Economic, Socio-Cultural, Technological (PEST) aspects, allowing for greater understanding of BIM implementation on various scales. The selection of the BIM frameworks was dependent on specific criteria with a minimum score of 4 out of 5 required to merit inclusion.

Three strategies for the creation of a BIM framework were discovered and were seen to vary across regions. The discovery of these strategies lays the groundwork for future research into the development of these frameworks to determine the potential advantages and downsides of each.

Keywords: BIM, Frameworks, Implementation, adoption.

1. INTRODUCTION

The building industry is a major contributor to countries' gross domestic product (GDP). By the third quarter of 2014, total spending in the construction sector reached over 3.8% in the Middle Eastern and African regions, compared to a stronger growth in Asian-Pacific countries where it

rose to 5.5% in 2010 (Economics, 2013). However, this sector also generates an abundance of waste every year (Dania, Kehinde, & Bala); the Gulf Cooperation Countries (GCC), for example, are estimated to generate 120 million tons of waste per year by 2020 (Hoornweg & Bhada-Tata, 2012).

Many initiatives are being developed to address the causes of waste and poor performance within the building sector. According to (Banawi & Bilec, 2014), *lean* (minimal waste, maximal productivity) and *green* (environmental sustainability) are used for waste identification and evaluation and can be integrated with *six sigma* (strategies to improve output quality) to provide an effective method for solving the problem of waste. Furthermore, according to (Allan Fred, 2016) Building Information Modeling (BIM) – a well-known methodology that combines technology and processes in the building industry – in conjunction with lean practices will reduce the amount of waste.

BIM aids with the validation of building processes and solving complex problems; it promotes simplicity and minimization of the occurrence of significant causes of waste, such as changes in orders and delays in data transformation (Banawi, 2017). The Aquarium Hilton Garden Inn Project is an optimal case study to demonstrate the potential cost savings using BIM. Originally the project was not designed using BIM, a Construction Manager at-risk was hired mid-project to coordinate the design and identify potential clashes; 55 clashes were found, which enabled a cost avoidance of $124,500; after considering the cost of BIM services ($90,000), total net savings to the project were $34,500 in the design development stage alone. Overall savings throughout the project were estimated at $200,000; similarly, the cost benefit in a second project, an academic building at Savannah State University in Georgia, United States (US) was approximately $1,995,000 (Azhar, 2011).

Due to the positive impact of BIM, countries such as France, Denmark, and the United Kingdom (UK) are requiring all major and public projects to be delivered using various levels of BIM (Azhar, 2011), however BIM implementation is inconsistent in other countries with similar building sectors, such as Saudi Arabia (KSA) and the United Arab Emirates (UAE). They are taking a divergent approach in implementing BIM, facing mitigating factors such as internal policy, reduction in the initial costs, and reduction in delivery time.

This paper provides in-depth discussion and analysis of prominent BIM frameworks, identifying critical common strategies. The research objective is to identify core frameworks, specifically:

- Allocate and select frameworks to be analyzed, according to the characteristics of the countries involved and the elements used to create BIM frameworks.
- Analyze the specified frameworks, including methods, tools, and processes.
- Identify mandatory guidelines to create a BIM framework customized to local requirements.

BIM implementation frameworks in specific geographical areas such as Asia, Europe, the US, and Australia will be discussed. A comparative study is done of different methodologies for BIM implementation, showcasing the conditions countries face when adopting BIM. The frameworks to be studied are chosen using specified criteria; this paper then identifies potential frameworks for future research and illustrates them in a comparison table, before the conclusion of the study.

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2. BACKGROUND

2.1. Building Information Modeling (BIM)

Building industry practices in countries worldwide have changed from paper-based design to Computer Aided Design (CAD) (Eastman, Eastman, Teicholz, & Sacks, 2011). In the mid-1980s BIM was used but under different names -- "*Building Product Models*" in the US and "*Product Information Models*" in Finland (Eastman et al., 2011). By the late 1990s BIM witnessed a boom that started when software began to advance and options other than CAD were made possible (Eastman et al., 2011). At the beginning of this new era (by 2002), the concept of BIM -with its ability to create a virtual reality model capable of storing a vast amount of information - started to spread globally (Schlueter & Thesseling, 2009). By late 2009 statistics showed that 48% of American architectural firms had transformed to using BIM technologies in their designs, with regard to BIM ability in modeling and analyzing energy in the early design stages (Yuan & Yuan, 2011). By 2016 many countries were mandating BIM in their construction markets with a variety of options including: open standards, future plan of work, and a clear plan for implementation (McAuley, 2017). Once users began exploring the possibilities introduced by this technology, the idea of BIM went in many directions and definitions appeared to introduce the technology to a wider audience.

The Construction Project Information Committee (CPIC), which provides guidance to institutes and governmental firms, defines BIM as a "*digital representation of physical and functional characteristics of a facility, creating a shared knowledge resource for information about it, and forming a reliable basis for decisions during its life cycle, from earliest conception to demolition*"(Sinclair, 2012b). Other definitions have recently appeared to define building information technology; most of them consider BIM to be a smart technology that helps with visualization and encourages collaboration between all members in the industry to coordinate designs. Despite that, many architecture, engineering and construction (AEC) communities have a faulty understanding of the concept of BIM as a software program or tool (Yuan & Yuan, 2011). Within GCC countries, the UAE has not mandated BIM in all of the emirates but started requiring it in Dubai for specific types of buildings since 2013. (Mehran, 2016) concludes that the implementation of BIM is misunderstood in the UAE and describes the importance of developing educational standards.

The adoption of new ideas requires a framework for proper implementation and use, and the clarity of the framework structure allows for a better understanding of the technology. BIM is considered a process starting from the project kick-off meeting and continuing to facility management. Thus, BIM modeling is a long process lasting throughout the project lifecycle; the frameworks identify the structure of its implementation, operation, and the involved parties.

2.2. BIM implementation structure

BIM implementation is becoming a trend in various developed countries. For the adoption of BIM to succeed, there must be a framework for implementation and extensive investigative studies on lessons learned by countries that have already successfully implemented BIM (examples include studies by the Australian Construction Authority and Ireland's Construction IT Alliance (CitA) on global BIM). At the end of this investigation of previous global lessons, an assessment study should be done on the current level of BIM in the local sector to create a better understanding

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International Journal of BIM and Engineering Science

Dec - 2019; Volume: 2 Issue: 2 page: 23-49 ISSN 2571-1075

of the role each participant in the government sector plays in leading the change to a BIM environment. Many successful work plans are based on standards that manage the use of a framework and cover the minimum quality requirements.

Furthermore, protocols need to be implemented to manage responsibilities and clarify roles. A framework's flexibility relies on the quality and clarity of its protocols and standards; moreover, an effective framework defines the range of coverage provided through documentation, information exchange, and coordination (Bui, Merschbrock, & Munkvold, 2016). Prior to planning for implementation, an imperative understanding is reached regarding factors to enhance the framework, such as the adoption plan and maturity level.

Many challenges face the adopters of BIM such as costs, and technical and legal issues (Alhumayn, Chinyio, & Ndekugri, 2017), but the need for finding solutions for the construction sector has motivated stakeholders to adopt BIM and maximize its business benefits, including time control, quality management, and cost reduction (Azhar, 2011). For example, in the Hilton Garden Inn hotel project in Atlanta, Georgia, US, BIM was used in the design coordination, conflict resolution, and work sequencing stages, leading to time savings of up to 1,143 hours (and cost savings of more than $200,000, as mentioned above)(Azhar, 2011).

The adoption of any new process in a variety of systems will experience inequalities in the level of progress. With regards to BIM, *maturity level* refers to the extent of adoption and collaboration integration levels among systems and industries. In addition, level of detail (LOD) is considered a significant aspect that determines the quality of models, and maturity levels are related to LOD in terms of the growth of BIM within industries. Analyzing frameworks that are already in use creates opportunities to enhance or replicate strategic elements in new frameworks, resulting in a more successful implementation of the technology with deeper understanding.

2.3. BIM implementation frameworks

The global construction sector has started using new technologies and developing the level of integration in the AEC industry, with technologies in use including drones, virtual augmentation, and the implementation of BIM. The level of BIM implementation has increased rapidly from 2016 and is still growing (Oleg KAPLIŃSKI), as governments plan for the use of BIM in their respective industries to enhance construction outcomes.

Regulation of the adoption of BIM is achieved by detailing the implementation process within the framework managed by the BIM champion, as these frameworks have organized the integration of BIM. Every industry has missions to achieve within the built frameworks, which likewise define the roles and responsibilities of the government. Every country has reached a different level of BIM adoption, based on a scale defined by (Succar, 2015) and reported in the CitA. The development of proven processes using BIM frameworks have enhanced the adoption process. In the case of the UK, the government established a BIM task group to set a foundation for leading the implementation of BIM processes, which allowed to it to reach maturity level 2. Other countries have witnessed BIM development in different areas and set individual standards, such as China, or in developed new technologies, such as Korea. There are more case studies of the process of BIM implementation around the world; (Succar,2015) references several about macro-adoptions, determining the conceptual structure and market analysis and thereby enabling BIM frameworks to be a more-defined measurement of BIM performance.

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International Journal of BIM and Engineering Science

Dec - 2019; Volume: 2 Issue: 2 page: 23-49 ISSN 2571-1075

Many researchers investigated the implementation of BIM while focusing on applicability and the technical aspects of implementation frameworks in detail (Alreshidi, Mourshed, & Rezgui, 2015, 2017); others focused on the implementation processes and regulation, along with the need for protocols or guidelines (Succar, Sher, & Williams, 2012; A. Wong, Wong, & Nadeem, 2009). Government strategies to implement BIM represented in the selected frameworks are reviewed in this research in order to recognize the achievements of all aspects of the frameworks in local construction industries. Analyzing these frameworks highlights their differences as well as the common critical areas that affect the implementation process. Further, the investigation contributes to the development of implementation processes, and creates a more profound understanding of basic requirements for future frameworks. The importance of the analysis is to review the possible strategies for BIM implementation, allowing researchers to understand the differences between frameworks, summing up current BIM frameworks to enable the development of new strategies, and facilitating the creation of new BIM frameworks.

The construction industry is a major contributor to any government's economy, and many countries aim to enhance the performance of this sector by adopting BIM. Finding the critical elements for successful adoption affects the implementation of BIM, from the local sectors to governmental visions and institutional programs. Since BIM relies on digital visual information technology, efficiency in the construction sector can be increased, as shown in approved case studies, by lowering the cost of buildings and improving communication among parties. Developing adoption frameworks based on local indicators is a critical step. BIM frameworks consider many aspects for effective implementation, starting from setting project milestones to the communication and construction processes throughout the project lifecycle. Regulating the processes based on BIM requirements impacts the construction sectors and effects change within the AEC industry regarding the uses of the technologies and tools.

The importance of finding common strategies is that it shows the value of each structural element of a BIM framework in every country, and the critical factors affecting the implementation of BIM. Moreover, the literature revealed a need to develop an understanding of the local construction sectors by identifying possible strategies for BIM implementation and facilitating more research in the field of BIM implementation by highlighting global frameworks and common elements. Thus, the local industries must understand the market and develop the implementation of BIM, and the review of previous frameworks and implementation strategies is part of the process of developing BIM frameworks.

The research value is based on the analysis of the frameworks and representation of national strategies for BIM implementation. As an investigation of the structure of BIM frameworks, this research revealed an in-depth methodology for the implementation of BIM frameworks based on a given criterion.

3. METHODOLOGY

A comprehensive literature review has been completed to analyze adoption frameworks in Table 1, including factors affecting the adoption process and the structure of frameworks. Many adoption frameworks have been used to achieve full integration modeling, and every initiative has different criteria related to regulations and standards. For this paper, five BIM frameworks have been selected for analysis and review, including emerging frameworks. The criteria listed in Table

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International Journal of BIM and Engineering Science

Dec - 2019; Volume: 2 Issue: 2 page: 23-49 ISSN 2571-1075

2 were used to select the frameworks in the study, using five major aspects scored 0 or 1, with a minimum total score of 4 out of 5 needed for the framework to be included in the review. A comparison is summarized in a separate schedule in the results of the study.

Country Framework	Authority	Framework title	Publishing year
UK	Royal Institute of British Architects	BIM overlay to the RIBA outline plan of work	2013
US	US General Services Administration	GSA: BIM Guide Overview	2007
Finland	BuildingSMART Finland	Common BIM Requirement 2012	2012
Australia	The Australian Construction Industry Forum and Australasia Procurement and Construction Council	A Framework for the Adoption of Project Team Integration and Building Information Modelling	2014
Canada	BuildingSMART Canada	Roadmap to Lifecycle Building Information Modeling in the Canadian AECOO Community	2014
Singapore	Building and construction authority	BIM Essential Guide For BIM Adoption in an Organization	2013
Hong Kong	The Government of the Hong Kong Special Administrative Region	Building Information Modelling (BIM) Standards Manual for development and Construction	2009
Scotland	Scottish futures Trust	Building Information Modeling (BIM) Implementation Plan	2015
UAE	Dubai Municipality	Circular 196, Circular 207	2013, 2015
Norway	Statsbygg	Statsbygg BIM Manual 1.2.1	2017
Malaysia	Construction Industry Development Board Malaysia (CIDB)	MYBIM Malaysia Publications	-

Table 1 Reviewed Frameworks - the selected frameworks

Criteria/ Framework	Government leadership	Established national database	Protocol availability	Education and training plan	Mandate for 3 years and above	Total
UK	1	1	1	0	1	4
US	1	1	1	1	1	5
Finland	1	0	1	1	1	4

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International Journal of BIM and Engineering Science

Dec - 2019; Volume: 2 Issue: 2 page: 23-49 ISSN 2571-1075

Criteria/ Framework	Government leadership	Established national database	Protocol availability	Education and training plan	Mandate for 3 years and above	Total
Australia	1	0	1	1	1	4
Canada	1	0	1	1	0	3
Singapore	1	0	1	1	1	4
Hong Kong	1	0	1	1	0	3
Scotland	1	1	0	1	0	2
UAE	1	0	0	0	1	2
Norway	1	0	0	0	0	1
Malaysia	0	1	0	1	1	3

Table 2 Evaluation for the selected frameworks

The existing literature fixed the structure of BIM frameworks, but there are different variables within the implementation process, as the factors -- Policies, Economic, Cultural, and Technological (PEST) factors -- change in the construction sector based on the BIM statutes for adoption. Each factor will be investigated and reported in qualitative results, to identify in depth the changes between elements in each framework. The comparison of the reviews included an investigation of the processes and the use of supporting implementation elements as the applied protocols, as well as educational training programs, databases and standards used, and the mandate year; these helped to measure the development of the framework and usage maturity level, while the structure of BIM implementation demonstrated the importance of each element.

4. REVIEW OF BIM FRAMEWORKS

4.1 United Kingdom

In 2011 the UK Cabinet Office identified the government construction strategy as a plan for growth. Because the construction industry is considered significant (representing 7% of GDP), BIM is one option that would enable the government to derive maximum benefit from this sector. Consequently, key members collaborated to establish an adoption plan named the Government Construction Strategy (GCS) in the same year (Cabinet Office, 2011). The target is to reduce waste in the public building sector by 40%, to decrease costs from £110 (US$140.995) million to £90 (US$115.359) million by 2020. The UK achieved level 2 BIM maturity, and this policy is planned to be a fixed requirement for future projects (GCS 2016–2020, 2016).

To contribute to the GCS, the Royal Institute of British Architects (RIBA) published a Plan of Work in 2013. (Sinclair, 2012a) In response to the government's commitment to BIM in every project in the summer of 2012, this change required collaborative integrated working methods and the standardization of frequently used definitions. In preparation for the 2013 fundamental review of its Plan of Work, the organization published the Green Overlay to the RIBA Outline Plan of Work in 2011, and the BIM Overlay to the RIBA Outline Plan of Work in 2012. Those overlays

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International Journal of BIM and Engineering Science

Dec - 2019; Volume: 2 Issue: 2 page: 23-49 ISSN 2571-1075

were integrated into the 2013 Plan of Work, which identifies eight task bars, some more flexible than others. Task bar 1 - Core Objectives remain fixed for all projects, while task bars 2, 3 and 4 - Procurement, Program, and (Town) Planning, respectively - vary widely and must be tailored to individual projects. Task bars 5 (Suggested Key Support Tasks), 6 (Sustainability Checkpoints), 7 (Information Exchanges), and 8 (UK Government Information Exchanges) are optional but recommended (see Figure 1).

The 2013 Plan of Work additionally sets out four main stages: preparation, design, construction, and hand over/in-use; the sub-stages include: strategic review, preparation and brief, pre-concept, concept and development, technical design, pre-construction, construction, in-use, and renovate and demolish (R&D), as shown in Figure 1 (Sinclair, 2012a).

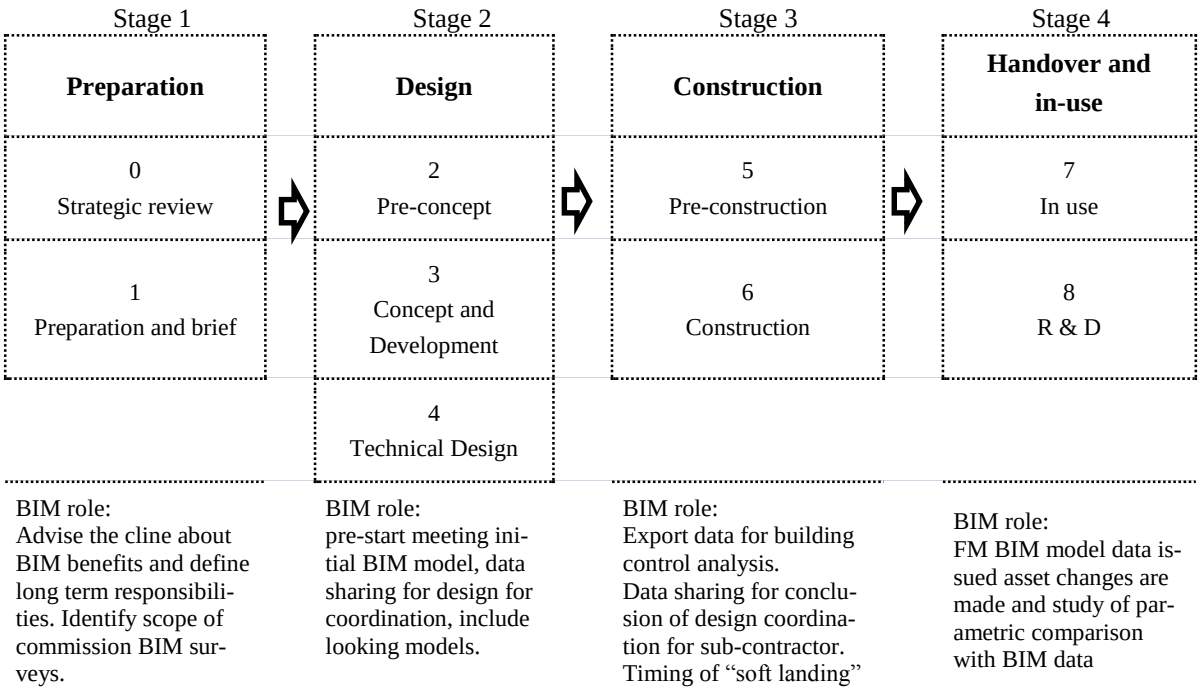
Stage 1
Stage 2
Stage 3
Stage 4
Preparation
Design
Construction
Handover and in-use
0 Strategic review
1 Preparation and brief
2 Pre-concept
3 Concept and Development
4 Technical Design
5 Pre-construction
6 Construction
7 In use
8 R & D
BIM role: Advise the cline about BIM benefits and define long term responsibilities. Identify scope of commission BIM surveys.
BIM role: pre-start meeting initial BIM model, data sharing for design for coordination, include looking models.
BIM role: Export data for building control analysis. Data sharing for conclusion of design coordination for sub-contractor. Timing of "soft landing"
BIM role: FM BIM model data issued asset changes are made and study of parametric comparison with BIM data

Figure 1 Stages and Sub-stages of Implementation during Project Lifecycle,

Preparation. In the first stage a design brief is created and added to the RIBA Plan of Work to inform stakeholders regarding strategies and specifics of individual projects. In addition, it is used to review feedback on previous projects, to identify procurement requirements, and to establish project objectives and quality standards. These sub-stages reflect primitive tasks outlined in each plan and show clients the benefits of BIM, thereby aiding construction professionals to clarify the cost, time, and facility management benefits for clients, and explain aspects relating to long-term responsibility, BIM input and output, and the scope of post-occupancy evaluation.

Design. The second stage refers to the movement from the conceptual to the technical level, with the inclusion of the outline proposal for structural design and preliminary cost estimation. Design development should involve coordination with structural teams and relevant parties to achieve the final stage. The technical design provides a project strategy and the matrix program. Implementing the design brief, preparing the data, agreeing to project quality standards, and reviewing the concept of BIM completed during the conceptual stage should initiate the pre-start

meeting during which the model is initialized and shared with the design team. The BIM level will then acquaint the design team with the project BIM data.

Construction. The third stage involves two sub-stages, first is pre-construction activities and the second is construction. In the pre-construction phase there is the production-information level, representing preparation of the project information and a review of the building contract, which is followed by additional information; and the tender level, which refers to the preparation and collation of detailed tender documentation as relates to tenders for completing the project, also involving the assessment of potential contractors' suitability for the project. Therefore, BIM is used to control the exporting of information in Industry Foundation Class (IFC) format to promote collaboration; conduct control analyses and detailed modeling, integration, and analysis; review construction sequencing, and work with the contractor.

The construction sub-stage covers closing the building contract, appointing the contractor, and administering the building contract to ensure practical completion. In this instance BIM facilitates the agreements regarding the timing and scope of "soft landings," that is, the coordination and release of the end of the construction level. Furthermore, the use of BIM data allows the effective overview of time and cost (4D/5D) for contract administration purposes.

Handover and in-use. The handover aspect refers to post-practical completion, the administration of the building contract after practical completion, and the commissioning of the building for a final inspection. The in-use sub-stage covers a model utilization for maintenance and facility development. Additionally, it requires a review of the performance of the project once it is in use and comparison with BIM data. This will allow the evaluation of asset changes and the study of parametric object information contained within BIM model data.

The RIBA framework organized the architectural practices and the use of BIM on a regulated level during the project lifecycle. The framework defined the roles of the architects in modeling and reported the responsibilities of the clients in project phases, as this element was clearer in the RIBA plan of work than in other frameworks which allowed for smoother implementation. Also, one of the targets for BIM implementation is to reduce waste, which RIBA achieves by controlling the processes and the pricing thereby reducing the waste of assets, time and resources. Moreover, defining the use of collaboration through BIM in the construction phases will reduce the traditional communication issues and poor timing, to allow for an effective project soft-landing and to manage the administration documentation for project delivery. Reaching maturity level 2 demonstrated the effectiveness of the BIM plan of work, but there are further challenges to drive the infrastructure of BIM to level 3.

4.2 United States of America

BIM implementation increased in the construction sector from 28% to 71% between 2007-2012 (McAuley, 2017). Although BIM is not mandatory in all states, several US organizations -- such as the National Institute of Building Sciences and the US General Services Administration (GSA) -- have taken part in initiatives to lead BIM implementation. The mission of the GSA is to enable federal agencies to serve the public sector. In 2003 the GSA and the Office of Chef Architect (OCA) introduced its national *3D-4D-BIM* program: 3D geometric models represent building components, and design or construction coordination; 4D represents the 3D and time factors that can inform project phasing, sequencing, and scheduling (GSA, 2007).

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International Journal of BIM and Engineering Science

Dec - 2019; Volume: 2 Issue: 2 page: 23-49 ISSN 2571-1075

According to the GSA framework, project stakeholders need to understand the roles and responsibilities of the project teams. Thus, clarity is important to define scope of services and review with all parties concerned, to ensure sustained success through integration between implementation and evaluation when using 3D-4D-BIM. During implementation planning and 3D-4D-BIM services, project teams should reference the applicable BIM Guide Series for the specific best practices and guidelines for technology-specific information (USGSA, 2007).

The framework further plays a role in defining the foundation level of all projects to ensure the use of advanced design technologies in the industry. It enables BIM integration in all future projects -- on smaller projects that require less advanced engineering, the standards of the framework address the BIM workflow; on larger projects the plan of work requires BIM to improve both synchronization and workflow.

The BIM framework is divided into sections A-J as shown in Table 3. Sections A, B, and C consider the basic data of a project, including numbering, site and building address, major milestones, and project contacts. For instance, section A covers the BIM Project Execution Plan Overview based on specifics of the project; it should provide a general overview similar to an executive summary. Section B encompasses the basic information required for the project and the list information related to it; this section affects the implementation of the plan in terms of numbering the participant teams in the modeling phase. Section C lists all the project contacts to ensure that the BIM goal of flattening the traditional project organization is attained; for example, a designer from the mechanical sub-partner must be able to directly contact the architectural designer to resolve any conflicts in the model.

Section D aims to establish objectives and goals for the project; regarding BIM the goal relates to the team, specifically to all team members understanding the project expectations. Therefore, subsection D-1 is used to define the goal clearly and to set out metrics that will be used to measure success in meeting goals on the project. Subsection D-2 clarifies the expectations set out in D-1, as a lack of clarity causes confusion and errors.

Section E represents the heart of BIM—collaboration—and defines it in the implementation of BIM in the project. Subsection E-1 describes the structure of the meetings that will be scheduled to facilitate team communication. Subsection E-2 explains the methodology to follow and indicates when model data is exchanged. Subsection E-3 refers to the tutorial on integration reviews for extended information on how to have successful review meetings. Subsection E-4 preps interactive workspaces, defined as “big-rooms,” and provides a layout of the team’s workspaces to allow the entire team to work on their models in a single space; typically, for co-located projects, the designer will bring their computers to the co-located site and work collaboratively as a group. Subsection E-5 shares documentation, models, and data with other technology-based communications as necessary; it defines the software required by the teams that needs to be installed and configured. Subsection E-6 defines the required training, promotes open discussions on training and education plans to extend the use of software packages, and requires further analysis of whether the team members understand the process. Finally, subsection E-7 addresses the team’s agreement on model integration methodology, including setup, objectives, and facilitation.

Section F represents quality control, a critical factor. This section is a significant checkpoint for GSA. Subsection F-1 demonstrates the implementation of quality control procedures to ensure quality management in both building and data. Subsection F-2 covers the performance of quality checks on the working teams. Sections G, H, and I address details of using the software within the

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International Journal of BIM and Engineering Science

Dec - 2019; Volume: 2 Issue: 2 page: 23-49 ISSN 2571-1075

framework. These sections of the plan of work are considered a reminder to the team to consult the BIM standards, and may require support from the IT team. Section J features a free template for teams to allow them to add any additional information that might benefit the project. Several suggested documents are listed, and the team is highly encouraged to add additional documents as needed. The categories, sections, subsections, and associated tasks listed in each section of the GSA 3D-4D-BIM are shown in Table 3.

Description	Section	Sub-section	Task
Basic level	A		project number
	B		site and building address
	C		project contact
Objectives	D	D-1	clear definition of goal
		D-2	expectations clarified
Core	E	E-1	structure of meetings
		E-2	when model data will be exchanged
		E-3	tutorial on integration reviews
		E-4	interactive workspaces
		E-5	sharing through technology-based communications
		E-6	required training
		E-7	model integration methodology
Quality control	F	F-1	implementation of quality control procedures
		F-2	performance of quality checks
Technology and standards	G H I		details of using the software within the framework
Free-template	J		any additional information

Table 3 3D-4D-BIM tasks, US

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International Journal of BIM and Engineering Science

Dec - 2019; Volume: 2 Issue: 2 page: 23-49 ISSN 2571-1075

The GSA are focused on the federal governance of the implementation of BIM; the scope of the framework has different areas, starting from the foundation for the projects to structuring the meeting in section D and in sub-section E4 the interactive workspaces. This framework showed a significant scope of work for different locations. The GSA covered the technical aspects for the 3D-4D modeling to benefit certain areas from BIM in order to develop the construction practices with the aim of reducing waste in the industry. There are other similarities with the RIBA frameworks, such as in defining a checkpoint for the modeling so that the goal of benefitting 3D-4D modeling is measured on every stage in the project. The framework covers the processes of modeling and conducting different aspects of regulation, as this considered to be a challenge with regards to the geographical coverage of that GSA framework. The ability to implement BIM on a large scale is achieved in this framework, which is applicable to many building sectors aiming to implement BIM and unify the rules of building on all scales, in order to reach higher maturity levels.

4.3 Finland

In 2001 the Finnish Ministry of Finance, through the state-owned enterprise Senate Properties, carried out several pilot projects to develop and study the use of product models (A. Wong, Wong, & Nadeem, 2011). Subsequently, in October 2007, Senate Properties released a series of standards and approved the use of models meeting IFC standards for the first time. More recently the City of Helsinki's Real Estate Department, the Hospital District of Helsinki and Uusimaa (HUS), Senate Properties, and the City of Vanuatu's Real Estate Department produced BIM project guidelines for clients (Bolpagni, 2013), presented as a thirteen-part series, as shown in Table 4.

	Document Name	Document description
1	General part	General Technical Requirements
2	Modeling of starting situation	- Modeling of the site and site elements - Source of data
3	Architectural design	- Modeling Principles in Architectural Design - General/ detailed design phases
4	MEP design	- MEP requirement model - System for MEP design - System BIMs for building automation design
5	Structural design	- BIM modeling of a renovation project - Definitions of different design phases - Detailed design phase
6	Quality assurance	- Quality client view/ Designer view - Quality Assurance - Responsibilities
7	Quantity take-off	- Model-based quantity take-off methods and connecting them to project management - decision making and modeling phases - quantity take-off process

8	Use of models in visualization	- The Objectives of visualizations - Illustrations and visualizations - Visualization at different modeling stages
9	Use of models in MEP analysis	- MEP analyses
10	Energy analysis	- Energy analyses in different stages of the project - Energy analyses programs
11	Management of a BIM project	- Principles of information model-based project management - BIM project management tasks from stage to stage - Construction preparation
12	Use of models in facility management	- BIM during operation and maintenance - Design software - Facility management BIMs updating procedure
13	Use of models in construction	- Contractors' Requirements for building Information models - Production data delivery into as-built BIM

Table 4 BIM Project Guidelines, Finland

The Finnish Government aims to support the design and sustainability construction process by implementing BIM used throughout a building's lifecycle, from the initial design stage and continuing even during use and facilities management (FM) after the construction project has been concluded, through the development of information models. In addition, the government aims to support design visualization, analysis of construction feasibility, enhancement of quality-assurance and data exchange, and the promotion of effective and efficient design processes (Finland, 2012a).

Therefore, the framework includes definitive project-specific requirements, and the setting and documentation of objectives and needs. It intends to provide decision-making support and promote all parties' commitment to the project objectives. To assist in design, the coordination of designs, and moving from the generation of models to the project stages, the framework calls for setting out needs, objectives, area and volume. Additionally, core activities are needed for reviewing site requirements in order to create a layout as per BIM requirements.

The next stage is creating alternative designs by investigating suitable basic options using rough spatial models. The design models from each discipline are expected be available to all disciplines, which is ensured by agreeing to sufficiently frequent uploads to the project server; a suitable schedule at this stage could be, for example, linked to regular design meetings. The early design stage follows the design of alternatives stage and involves the further development of architectural BIM. The client's requirements are updated in the previous stage to conform to the decisions made; in the early design stage, the client's tasks include overseeing the design and approving the design solution for the subsequent detailed design phase. BIM enables fast, illustrative, and interactive visualization and analysis, which support communication and decision-making (Finland, 2012b).

The detailed design stage is similar to the early design stage, with the exception that the level of accuracy of the information generated is significantly higher. The design solutions are finalized to be released for tenders, and all models prepared for the project are further inspected using detailed information. It is noted however, that a substantial part of the detailed design stage

information still needs to be generated in the form of traditional design documents. The information content and accuracy levels of the models are defined in Series 3–5 of the domain-specific BIM instructions.

In the construction stage, the use of BIM by contractors relates to organizing the production processes. This section is a description of the primary applications of the models. 3D visualization creates benefits on many different levels: models offer a better way to study the designs and structures, and they facilitate the planning of installation procedures and the coordination of the work as well. A quantity that is BIM-based launches a rapid calculation process and provides an accurate result, effective models, and report templates to reduce duplicated work significantly. This improves the productivity of construction overall. During the last stage in the framework, commissioning represents the generation of documents out of the model formats to create a direct manual for maintenance, essential to generate as-built models (Finland, 2012c).

The Finnish government has established a series of manuals published in this framework to organize communication during the modeling and implement the protocols to avoid problems. Still, the level of governance of BIM processes is not clear, and as shown in the review this framework relies on open standards to benefit from its practices. The main objectives for BIM implementation are not clear, which is one of the missing elements even though BIM has been considered a tool in Finland since the 80s. The implementation of BIM over this long period of time has resulted in a rich framework with detailed modeling and clear polices. The process of BIM in the Finnish industry considered the energy analysis of building models as well -- this is considered to be a valuable element that doesn't exist in many frameworks. Moreover, much information detailing was added for project coordination and management (which also appears in the RIBA framework). The richness of these frameworks included aspects of facility management protocols and guidelines, covering the quality of the facility while running and as-build drawings, resulting in the Finnish government being ready to develop more processes and regulation of BIM technologies.

4.4 Australia

Construction industry productivity is fundamental to Australia's economy. The building and construction industry accounts for 7.8% of Australia's GDP, employing 9.1% of the workforce and contributing AUD$99.4 billion to the local economy in the 2011–2012 financial year. By the end of June 2012, the building and construction industry generated $305 billion in total income (ACIF, 2014). A study by the Allen Consulting Group determined that accelerated adoption of BIM would increase GDP growth in Australia by 0.2 basis points in 2011, with an estimation of a 5 basis points increase by 2025 (ACIF, 2014). Moreover, the benefit-cost ratio of early adoption of BIM would be around 10 (assuming a $500 million adoption cost). These statistics clearly indicate potential benefits and productivity gains through the adoption of BIM.

The Australian Construction Industry Forum (ACIF) and Australasia Procurement and Construction Council Inc. (APCC) took the lead to establish the Australian BIM framework, aligning the government with key stakeholders to adopt information modeling. ACIF and APCC have identified seven elements, supported by objectives and actions, where industry and government could encourage and promote increased adoption of Project Team Integration (PTI) and BIM. The Australian framework discusses the adoption level as four stages: 1) from the

standard base to the 2D manual drawing; 2) the modeling level; 3) collaboration; and 4) reaching full integration (ACIF, 2014).

Reviewing the Australian scope of work is the first objective towards constructing a framework as it relates to adoption levels, the various projects using BIM, and innovative procurement processes. The challenges ahead of the international adoption for BIM were also documented. These primary elements were reviewed before setting the guidelines for communication, investment, methodology, policy, skills, social acceptance, and the role of qualified "change leaders" to determine the success of the plan, as observed in the implementation of technology (in this framework, change leaders are referred to as "BIM champions"). In addition, educational needs are identified, specifically the role of universities and training programs in highlighting the technology, educating practitioners about its benefits, and leading change.

Procurement and contracting are identified as crucial factors in implementing BIM in the Australian framework, with the importance of early engagement of the contractor in the initial design stages to maximize benefits. Factors during the contractual level -- arrangements with the working teams, the priority of documents, expected risks and attendant risk management and sharing, and legal considerations (copyright, licensing, data access, etc.) -- are addressed. Another aspect, procurement cover, is the tender approach with a goal of increasing integration on a competitive basis.

Controlling human responses to the framework requires protocols, and the National Building Specification (NATSPEC) guidelines were established to clarify roles, responsibilities, and the standards expected of project teams. Of primary importance is to create a solid foundation for clients to evaluate their projects, save money, and to improve performance; another objective is to assist management via controlling the organizing, planning, and design processes (NATSPEC, 2011).

The BIM framework extends the construction stage to facilities management, clarifying and maximizing the benefits of BIM throughout the lifecycle of the project and as an aspect of asset management. The objective of information exchange and the use of an object library, such as the UK NBS library, allows design teams to use fully specified generic objects in designs, promoting the pooling of resources and the provision of the best service possible for project stakeholders. Consequently, standards are required in the framework to manage the use of data, and as in any computer-based technology, information standards allow and facilitate universal use and understanding

The Australian framework has included a strong foundation for the implementation of BIM within the industry, as their study has covered many aspects to find the best practices in BIM. The framework defines the use of BIM on a governance level, but without considering the execution and local measurement of the existing conditions for BIM, which are not highlighted in the framework. NATSPEC was intended to fulfil the need for BIM protocols in practice; however, compared to the Finnish framework and GSA, the Australian framework has a shortage in practical areas for implementation of BIM within the industry. Their work defining the milestones, objectives and the minor aspects, including contracting details, are essential elements of a BIM framework, but the technical aspects, roles and responsibilities and the hierarchy of execution in all project phases is likewise important. Several aspects could therefore be improved as defined in the existing maturity level, with the goal of achieving higher levels in determined years. Achieving the phases of BIM implementation and reaching the checkpoints for each stage will increase the

Available online at: http://bimarabia.com/IJBES/

International Journal of BIM and Engineering Science

Dec - 2019; Volume: 2 Issue: 2 page: 23-49 ISSN 2571-1075

level of understanding within the sector; open standards assist in the development of the framework but cannot fill the local sector standards, as an assessment of the local industry was not included.

4.5 Singapore

The Building and Construction Authority (BCA) in Singapore began the use of BIM in 2010 by creating the initial version of a BIM roadmap; in 2015, the second version of the roadmap was published authorizing the use of BIM (McAuley, Hore, & West, 2017). The second version is similar to the Hong Kong roadmap, focusing on the transformation process, research and development of BIM applications, and facilities management. The organization's publication focused on leadership, planning, information, processes, people and client involvement as major factors in creating a guideline (Committee, 2013). The Singaporean construction authority published a BIM guide in 2013 to define the deliverables and processes for BIM in construction projects for the involved professionals. Table 5 illustrates the main components of the guide for BIM implementation.

Section	Sub- Section
1. Introduction	1 BIM Deliverables 2 BIM processes 3 BIM professionals
2. BIM execution plan	-
3. BIM deliverables	1 BIM elements 2 Attributes of BIM elements 3 BIM objectives and responsibilities 4 Compensation expectation 5 Other additional value
4. BIM modeling and collaboration procedures	1 Individual discipline modelling 2 Cross-disciplinary model coordination 3 Model and documentation production 4 Data security & saving 5 Quality Assurance and quality control 6 Workflow of design-build projects 7 Workflow of design-bid-build projects
5. BIM professionals	-

Table 5 Singapore BIM Guide 'version 2', Singapore

The Singaporean building industry has a basic layout for the implementation of BIM, but the level of assessment in the local sector is not included which makes it challenging to reach an in-depth understanding of BIM in the sector. Measuring is associated with setting the maturity of the framework and defining the areas where further development is needed to develop comprehensive

Available online at: http://bimarabia.com/IJBES/

International Journal of BIM and Engineering Science

Dec - 2019; Volume: 2 Issue: 2 page: 23-49 ISSN 2571-1075

frameworks. In the case of Singapore many practical aspects are not displayed, such as modeling and phasing of a project and the guidelines and standards for modeling.

4.6 Hong Kong

The Construction Institute Council (CIC) is leading Hong Kong to implement BIM. In 2015 the CIC published a roadmap for the strategic implementation of BIM in Hong Kong in the construction industry to enhance the construction sector, introducing BIM in stages ("CIC Building Information Modelling Standards (phase One)," 2015). The implementation plan is designed to focus on main areas that create the framework, including: collaboration, benefits, standards, insurances, information sharing, education, digital capability, risk management, and global competitiveness. The transformation of these areas via initiatives is part of the concepts underpinning the framework; in contrast the Hong Kong Housing Authority has mandated the use of BIM in all of their projects and published a series of guidelines and library manuals for users and designers (Region, 2009).

The use of BIM on a small scale can be managed with internal regulations and processes as in the Hong Kong Housing Authority. On the other hand, a broader level of strategic planning requires deep investigation and creation of a foundation; the CIC's efforts towards strategic implementation is clearer but in the case of BIM there are more elements needed, such as databases and an organized level of governance over the implementation processes.

4.7 Scotland

The government of Scotland planned to mandate BIM for public sector projects in 2017, digitizing the construction industry by following British implementation standards to achieve level 2 ("Building Information Modeling (BIM) Implementation Plan," 2015). The stages of implementation have been segregated into five periods: 1) assess BIM maturity and define thresholds; 2) mobilization; 3) pathfinder project; 4) development of Scottish government guidance; and 5) launch of BIM level 2. The first stage started in 2015 with the measurement and definition of the BIM implementation plan, assessing BIM maturity level, and defining qualified BIM projects. The second stage outlines the government's role, communication during implementation, and the education plan. By 2016, a selection of pathfinder projects determined the delivery team and the methodology. The previous stages required the Scottish government to review the components of maturity level 2, which led to the development of BIM guidance (fourth stage). The final stage started in 2017 by launching level 2 of BIM: setting the level of communication between authorities, the industry, and the public sector; and monitoring the implementation.

The framework of the Scottish government, considered in the early stages of the implementation and its approach, is oriented to find a practical solution for the local constriction sector -- starting from the assessment of BIM maturity to create better understanding of the possibilities of BIM enhancements, to working on pathfinder projects to examine the strategies of the implementation of BIM. The strategy of moving towards direct implementation requires rapid developments, as appearing in stage two, that focus on communications and later on government-level coordination. The Scottish plan of work focuses on guiding the change from the bottom of the hierarchy, starting from projects to changing decisions in the last stage.

Available online at: http://bimarabia.com/IJBES/

International Journal of BIM and Engineering Science

Dec - 2019; Volume: 2 Issue: 2 page: 23-49 ISSN 2571-1075

4.8 Norway

The government of Norway mandated the use of BIM in the construction industry in 2016. Their framework focuses on guidelines throughout the building process. First, generic requirements define the deliverables and BIM requirements obtained from clients. Second, domain requirements focus on practices such as architecture; landscape; interior design; geotechnical, structural, electrical, and acoustical elements; fire safety; engineering and as-built modelling; and facility management. Third, the quality and practices division complete their required analysis and the practices of modelling. Finally, scientific classifications are based on technical spaces, and mechanical and electrical entities (Statsbygg, 2013).

The implementation of BIM in the Norwegian construction industry is in early stages, but the level of detail within the framework shows a practical and fast orientation towards implementation. The checkpoints for the processes and quality of the modeled project in the framework show a high technical consideration. Still, many needed areas can be defined as the objectives of BIM.

4.9 United Arab Emirates

The government of the UAE has initiated the adoption of BIM in the city of Dubai in 2013. The leading champion of this effort is the Dubai municipality, with a mandate for using BIM (published through Circular 196) for specific types of projects - buildings with a height above the 40th floor, and any building project with an area equal to or greater than 400000 square feet. In 2015 the requirements were updated (through Circular 207) to include all governmental projects, and projects for buildings with a height above the 20th floor and/or an area equal to or greater than 200000 square feet (Hany, 2015).

The strategy of the Dubai municipality for BIM implementation focuses on mandating the use of BIM in the private and public sectors via regulations, as with many guidelines adopted from global standards to regulate the implementation of BIM. The framework of BIM in the Dubai municipality considers the use of BIM as a tool without setting a foundation for its implementation or a roadmap for the use of BIM.

4.10 Canada

Canada intended to develop a plan to integrate BIM into their construction industry in 2014, and since then the Canadian BIM council has issued a roadmap for BIM adoption with a target to achieve integration by 2020. After establishing the roadmap a protocol was placed to manage implementation, with levels of implementation ranked from *level 0* to *level n*: level 0 for isolating in modeling, level 1 for networking and coordination, level 2 for collaboration, level 3 for reaching the full integration, and level n represents “unified” (McAuley et al., 2017). The roadmap objectives therefore are achieving engagement, development, education, deployment, sustainability, and evaluation of BIM. The plan extended to 2020 to enable the adoption of BIM at all levels. The approach for 2017 was to engage and create a movement to adopt BIM, develop a BIM guideline and standards, and create an education plan to deploy information and work by representing it through a collaboration plan. Evaluating the maturity level can be associated with measuring the adoption, moreover the Canadian government is planning to sustain the adoption via integration with international frameworks ("Roadmap to Lifecycle BIM | buildingSMART Canada,"). The Canadian framework is not in the execution stage. The framework target is to

achieve full integration with the further aim to increase education and sustainability. The main lines for the framework are clear, but the foundation of the framework is missing -- the technical aspects as well as the databases and communication -- showing there is a need for an investigation of the technical aspects. The stated intention for the integration of BIM by 2020 shows that the plan is still in progress, and the Institute for BIM in Canada (IBC) has launched BIM and Revit protocols.

4.11 Malaysia

The strategic implementation of BIM in the Malaysian construction industry was started in 2015 by the Construction Industry Board (CIDB). The main framework schemes include standards, collaboration, education, BIM library, BIM guidelines establishment, and legal issues. Those elements are to be researched in the context of Hong Kong and Singapore, as well in relation to local industry needs (Latiffi, Mohd, Kasim, & Fathi, 2013). On the other hand, the Construction Industry Transformation Program (CITP) developed the implementation of BIM within the construction industry in response to the economic growth, by launching a series of publications to clarify the roles of BIM within the industry in awareness, readiness, and adoption; likewise, a BIM execution plan was announced by myBIM Malaysia.

The plan of Malaysia is to develop the implementation of BIM within the industry by execution, and as result of that action issues in the legal aspects were found. This led to a reassessment of the process of BIM, its adoption, and defining the strategic layout. Determining leadership for BIM adoption could help achieve better results.

5. RESULTS

The review highlighted the most critical areas for the researchers in the field of BIM implementation, as well as the essential factors within every country and organization strategies, and contributions to the process of adopting BIM. The study covered many aspects, such as the role of the protocols within the frameworks, the objectives of the frameworks, the structure that supports the implementation within countries, in addition to other strategies. The comparison of the frameworks was the critical aspect of the study. The differences between the frameworks were highlighted based on political, economic, socio-cultural, and technological (PEST) factors, as this allowed in-depth insight into the processes placed to achieve the objectives of BIM implementation and clearly showed the strategies within the frameworks.

Comparisons between the frameworks based on the PEST factors are shown in below. The first factor, Political, highlights the purpose of using BIM within the industry. Setting the governmental objectives of the implementation is essential, and the possible benefits should be clarified associating the champion needed to achieve it. Every country has set milestones for the implementation of BIM, and the leader of measuring the outcomes of the frameworks, as shown in Table 6.

Available online at: http://bimarabia.com/IJBES/

International Journal of BIM and Engineering Science

Dec - 2019; Volume: 2 Issue: 2 page: 23-49 ISSN 2571-1075

Framework	Description	Champion
United Kingdom	The aim was to maximize the benefits of the construction sector, digitize the industry, and improve communication within the industry.	BIM Task Group
United States of America	Not all states mandate the use of BIM, but GSA applied it in federal projects, taking the lead to benefit from 3D-4D features.	GSA and the National Institute of Building Sciences
Finland	The government has supported the use of BIM since 2007, aiming to encourage effective design by supporting the champion of BIM adoption.	Senate Properties
Australia	The Australian and New Zealand governments are aware of the benefits of BIM and look to enhance the industry as the construction sector is considered the fifth large industry in the economy.	ACIF and APCC
Singapore	The government adopted BIM to improve benefits 20-30% and use a highly integrated technology.	BCA

Table 6 Political factor in the frameworks

The second factor is the Economic response to the embedding of technologies and processes, as this factor focuses on the government role as an investor in the technology and developer of regulations. The respective GDPs of the countries show the need for BIM development, considering expenditures, returns and the waste in the industry. Establishing the level of the investment and the expected Return of Investment (ROI) considered in the frameworks shows the level of the support of BIM; this is viewed as a valuable factor, delineated in Table 7.

Framework	Description	Champion
United Kingdom	The government found the need to develop the GDP of the construction sector and reduce waste by 2020 to 40%.	UK Cabinet office
United States of America	Aims to improve productivity and reduce waste throughout all phases of the building industry, as GSA found a waste of US$15.8 million in 2002.	GSA
Finland	The government invested in BIM through the efforts of Senate Properties, to lead implementation and benefit long-term from investment in BIM.	cubism
Australia	The rapid growth of the construction GDP shows a high value for developing the industry, and the framework to implement BIM and PTI has been placed for maximum benefit.	ACIF and APCC
Singapore	The government aims to improve the construction industry's productivity by 20-30%. The BCA launched a funding program to support the implementation of BIM.	BCA

Table 7 Economical factor in the frameworks

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International Journal of BIM and Engineering Science

Dec - 2019; Volume: 2 Issue: 2 page: 23-49 ISSN 2571-1075

The third factor is Socio-cultural, and many sources from literature considered the resistance to transformation as a barrier to BIM implementation. The frameworks define roles and responsibilities, as shown in the protocols, to clarify the tasks for the stakeholders. The amount of awareness by the AEC workers and their willingness to embrace the protocols, is critical for an effective implementation of BIM. Hence, every country developed a training program and, in some cases, even required the embedding of BIM within the education system. Table 8 shows the Socio-cultural factor in the frameworks.

Framework	Description	Champion
United Kingdom	The cultural resistance to change is considered a barrier to the mandated accelerated adoption; RIBA developed an education plan and training for BIM.	BIM Task group, RIBA
United States of America	Section D, established by GSA, clarifies the roles and responsibilities of all working team members.	GSA
Finland	The workers within the government reached 93%, and the construction industry has relied on BIM, ICT from 2007, showing a high awareness of the use of BIM.	coBIM
Australia	The challenges related to socio-cultural elements are considered to be solved by the support of the top of the hierarchy -- management leads the transformation as the champion and facilitates training programs.	ACIF and APCC
Singapore	There is an objective of building a hub to support the AEC in developing the implementation. Also, a certification is provided for undergraduate students as well as a diploma and training in BIM.	BCA

Table 8 Socio-cultural factors in the frameworks

The main forces in BIM lie within the technological factor, as the relations and communications among parties and the applied ICT are defined in this section of the framework, in addition to the level of collaboration among stakeholders, the national databases and library in-use. The technology in use has many aspects covered and defined, and this section is considered the foundation for BIM implementation. Table 9 shows the relation between the frameworks as regards this factor.

Framework	Description	Champion
United Kingdom	Transformed to the use of E-procurement within the UK, and maturity level 2 shows that the industry achieved the level of collaborative modeling.	BIM Task group
United States of America	GSA established a technical specification as section E, with seven sub-sections to cover the technical aspects within the series of implementation.	GSA

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International Journal of BIM and Engineering Science

Dec - 2019; Volume: 2 Issue: 2 page: 23-49 ISSN 2571-1075

Framework	Description	Champion
Finland	The use of IFC within the industry of Finland, as the minimum requirements of BIM implementation, follows the publication by coBIM in 2012.	coBIM
Australia	The framework aims to create an interactive platform for workers within the industry, and to build a cloud-based service and high security system.	ACIF and APCC
Singapore	Singapore has applied e-submission, and BCA has mandated the use of e-submission for digitizing the industry by BIM and IDD.	BCA

Table 9 Technological factor in the frameworks

Every country has different milestones and objectives for the implementation of BIM, therefore the order of the framework components is different; however, there is a fixed component for the implementation of BIM. The UK framework has developed based on many aspects, starting from setting a framework to measuring the outcome and fixing the framework – with that task assigned to the BIM Task Group. On the other hand, the USA framework placed by GSA targeted the application of 3D-4D practices to many projects in the entry stage; also, the established series of documentation showed that it is the main focus on all aspects of the implementation. The Finnish framework covered many aspects in standardizing the implementation, focusing on the publications of modeling specifications the role of the stakeholders within the AEC. The Australian framework has formatted the main lines of the implementation process, covering the aspects related to BIM implementation by the stakeholders, applied protocols, standards, and technology; this allows development within the process of the implementation. The Singaporean BCA supported the implementation of BIM through funding and training programs. Use of BIM has been recognized as important for one of the goals targeted to digitize the industry; all of the plans were targeting improvement in the areas of time and cost as contributors to enhancement of industry productivity.

For the other frameworks, as shown in Table 10, the level of BIM adoption is differentiated based on the construction industry statutes within the country – whether the methods for BIM implementation follow the approach of using open standards, or mandating the use of BIM, or no specific requirements.

Framework	Description	Mandate year
Hong Kong	The construction industry has developed the implementation of BIM, with academia taking a role in education. The framework shows the strategic implementation plan and assessment of the industry.	Mandate in place since 2014
Scotland	The Scottish government has mandated the use of BIM, dividing it into two phases aiming to achieve level 2, relying on pathfinder projects to establish the implementation of BIM by Scottish Futures Trust.	Introduce level 2 in 2017

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International Journal of BIM and Engineering Science

Dec - 2019; Volume: 2 Issue: 2 page: 23-49 ISSN 2571-1075

Framework	Description	Mandate year
Norway	The Norwegian government has outlined the framework in-use to define professional practices for the AEC, the updated development was established in 2015.	2016 open standards
UAE	The implementation of BIM is mandated in the city of Dubai with specific requirements; there is local standard, but misunderstanding of BIM and the local standards.	Restricted mandate in place
Canada	Canada is still processing the implementation and the framework in-place is considered a roadmap, with protocols to implement BIM with an open standard to achieve level *n*.	2014 - 2020 mandate will be placed
Malaysia	The plan of Malaysia aims to adopt BIM based on a series of publications clarifying the roles of BIM within the industry in awareness, readiness, adoption, and BIM execution plan.	CIDB

Table 10 The secondary frameworks comparison

Table 11 represents a summary of the data collected (including the maturity level, standards, procurement system, and the champion role) from each of the five BIM frameworks chosen for analysis, comprising a comparison of the reviewed frameworks and the criteria formulating them, including: governmental support and leadership; mandatory periods; development and maturity level; and availability of standards, databases and protocols.

Criteria/ Framework	United Kingdom	United States of America	Finland	Australia	Singapore
Government leadership	Exists	Exists	Exists	Exists	Exists
Mandate year	2006	2009	2001	2012	2015
Maturity level	Level 2	N/A	Level 1	Level 0	N/A
Standards availability	BIS	GSA technical standards	ISO	ISO	Singapore BIM Guide
Protocol availability	Exists	N/A	Exists	Exists	Exists
Database availability	NBS national BIM library	IFD Library and International Standards	N/A	NATSPEC	Building Smart
Procurement systems	E-procurement	Design-bid-built	IPD	N/A	N/A
Education and training plan	Mandatory	N/A	Mandatory	Optional	N/A

Available online at: http://bimarabia.com/IJBES/

International Journal of BIM and Engineering Science

Dec - 2019; Volume: 2 Issue: 2 page: 23-49 ISSN 2571-1075

Criteria/ Framework	United Kingdom	United States of America	Finland	Australia	Singapore
BIM Champion name	RIBA	GAS	Senate Properties	ACIF and APCC	Building and Construction Authority

Table 11 Summary of the major components of BIM implementation frameworks

5. CONCLUSION

Several aspects of BIM implementation and adoption were considered in this study to show the importance of assessment of frameworks and to learn from previous lessons (as is being done in Malaysia) and create a better understanding of the processes for effective BIM implementation. The work of BIM Champions ("change leaders") in each location is to evaluate the implementation of BIM and control the direction of its development, as in the UK where their strategy has included it as part of its Plan of Work. These Champions have proven to be a key element in measuring and assessing needs to enable achievement of technology adoption, GDP ratio enhancement, or avoidance of exceeding budget and time targets within projects.

As one of the objectives of this study is to analyze selected frameworks to create better insight into the main elements of the frameworks, it is noted that there are many strategies for the creation of BIM framework: first, the assessment of the industry (as in the case of the UK and Canada), which results in a longer process for forming the framework; second, developing the framework within the implementation process (an approach followed by the UAE and Australia) which allows for a longer process and quick solutions; and third, staging the building process in consideration of specific sectors (as in the UK-RIBA), where the framework focuses on targeted areas – in the UK context, the architectural practices and the roles between the AEC and the clients based on the stage of the project.

Another objective of this research was to investigate the importance of local requirements to set BIM frameworks. The differences between the PEST factors showed the need for understanding the complexity of BIM implementation and aligning the common elements that are necessary for BIM implementation. Even more, the importance of the assessment of the local construction sectors to find the critical success factors (CSF's) for BIM in the different building sectors is required to facilitate the implementation of a BIM framework. The creation of BIM implementation strategies requires many elements, skills, and an understanding of BIM, as the construction industry is linear process that requires a hierarchy and chain of order. The different strategies uncovered through this research are considered a valuable asset for further framework development -- summing up the possible strategies for BIM implementation, and determining the potential issues of region differentiation and the PEST aspects of local industries.

Essentially, the development and adoption of BIM-related technology are significant for the building industry with regards to the global trend of adopting BIM and including it in plans of

work. This study facilitates future research on the topic of BIM adoption by providing an overview of the frameworks available, with a future goal of creating a fixable BIM framework. The current study highlights the importance of assessment in the framework creation process and directs further study to investigate and identify local BIM Champions. Future studies can also critically compare these identified frameworks to facilitate decision making on the most suitable method for a project.

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Closure Statement

At the end of this issue, we wish it is a good and a distinct issue, we would like to thank all those who contributed to its achievement since the first idea until today **31-12-2019**. Thanks to the BIMarabia Research Center, the publisher of the Journal. The International scientific board who led the review and follow-up and coordination over the whole last six months of effort to accomplish this work. Based on a sense of responsibility and passion for scientific research, we have provided every possible means to monitor research and scientific papers interested in the field of BIM, and its review followed up with the distinguished authors to reach the best scientific level. We promise you more valuable papers in the next issue. We also sincerely invite you to put forward your constructive views and suggestions for the development of the Journal. And a special invitation to contribute to the publication of your articles and research in the field of BIM and modern management and other areas covered by the Journal and mentioned at the beginning of the issue.